



**DEPARTMENT OF THE ARMY  
US ARMY INSTALLATION MANAGEMENT COMMAND  
HEADQUARTERS, UNITED STATES ARMY GARRISON, REDSTONE  
4488 MARTIN ROAD  
REDSTONE ARSENAL, ALABAMA 35898-5000**

REPLY TO  
ATTENTION OF

**Environmental Management Division**

**MAR 29 2018**

**Mr. Steve Cobb, Chief  
Chief, Land Division  
Alabama Department of Environmental Management  
Post Office Box 301463  
Montgomery, AL 36130-1463**

**Dear Mr. Cobb:**

**References:**

- a. Installation Restoration Program at Redstone Arsenal, Alabama (EPA ID AL7 210 020 742).**
- b. Revision 1 Resource Conservation and Recovery Act Facility Investigation Report, RSA-147, RSA-148, and RSA-149 Groundwater Sites, Groundwater Units GW-03, GW-04, and GW-05, Operable Unit 19, March 2018**
- c. Redstone Arsenal's Alabama Hazardous Wastes Management and Minimization Act Hazardous Waste Storage Facility/Thermal Treatment/Solid Waste Management Unit Corrective Action Permit, dated September 30, 2010, modification #11, dated January 8, 2018.**

**This letter transmits the submittal of the Revision 1 Resource Conservation and Recovery Act Facility Investigation Report, RSA-147, RSA-148, and RSA-149 Groundwater Sites, Groundwater Units GW-03, GW-04, and GW-05, Operable Unit 19, March 2018, US Army Garrison-Redstone, Madison County, Alabama for your review.**

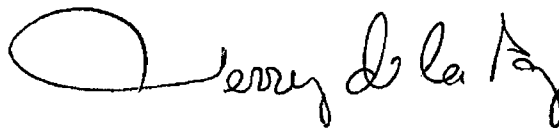
**The RSA-147, RSA-148, and RSA-149 Resource Conservation and Recovery Act Facility Investigation report was completed using the following screening values. Groundwater sample results were evaluated against the 2003 background screening values for metals and the groundwater EPA Maximum Contaminant Levels or the November 2017 EPA Regional Screening Levels for tap water. The evaluation criteria used in the RSA-147, RSA-148, and RSA-149 Resource Conservation and Recovery Act Facility Investigation report are adequate to assess whether the nature and extent of contamination has been defined at this site.**

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Copies of this correspondence are being furnished to Mr. Will Overstreet, Alabama Department of Environmental Management; Mr. Daniel Arthur, Alabama Department of Environmental Management; Mr. Alan Farmer, Resource Conservation and Recovery Act Division; Ms. Michelle Thornton, US Environmental Protection Agency, Region 4; Ms. Carol Monel, US Environmental Protection Agency, Region 4 RCRA; Mr. Paul Higgs US Army Environmental Command; Mr. Paul Fluck, US Army Corps of Engineers; Mr. John Guarisco, Alabama Department of Public Health; Ms. Samantha J. Strickland, Environmental Permits and Compliance; Mr. Emery Hoyle, Wheeler National Wildlife Refuge; Mr. Larry Tannenbaum, US Army Public Health Center MCHB-IP-REH and Mr. Brian Roberson, Marshall Space Flight Center.

My point of contact for this matter is Mr. Clint Howard, Environmental Management Division, 256-842-3702 or e-mail [joseph.c.howard1.civ@mail.mil](mailto:joseph.c.howard1.civ@mail.mil).

Sincerely,

A handwritten signature in black ink, appearing to read "Terry de la Paz". The signature is fluid and cursive, with a large initial "T" and "P".

Terry de la Paz  
Chief, Environmental Management  
Division

Enclosure



**Revision 1**  
**RCRA Facility Investigation Report**  
**RSA-147, RSA-148, and RSA-149, Groundwater Sites**  
**Groundwater Units GW-03, GW-04, and GW-05**  
**Operable Unit 19**  
**U.S. Army Garrison-Redstone**  
**Madison County, Alabama**  
**U.S. EPA ID No. AL7 210 020 742**

**Prepared for:**

**Mission & Installation Contracting Command**  
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**2107 17th Street**  
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**Prepared by:**

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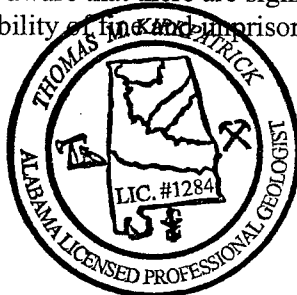
**Contract Number W91ZLK-09-D-0006**  
**Project Number 150524**  
**Task Order 0012**


**March 2018**

**RCRA Facility Investigation Report  
RSA-147, RSA-148, and RSA-149, Groundwater Sites  
Groundwater Units GW-03, GW-04, and GW-05  
Operable Unit 19  
U.S. Army Garrison-Redstone  
Madison County, Alabama  
U.S. EPA ID No. AL7 210 020 742**

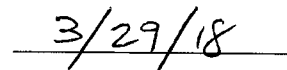
**Certification**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.





Thomas M. Kirkpatrick Alabama PG No. 1284

  
Date

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## ***Executive Summary***

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This report presents the results of the Resource Conservation and Recovery Act facility investigation for the RSA-147/148/149 groundwater units (GW-03/04/05, Operable Unit 19), conducted under the Resource Conservation and Recovery Act Corrective Action Program (U.S. Environmental Protection Agency ID # AL7 210 020 742) in accordance with the Alabama Hazardous Wastes Management and Minimization Act Hazardous Waste Storage Facility/Thermal Treatment/Solid Waste Management Unit Corrective Action Permit issued on September 30, 2010 and last modified on February 15, 2017.

The RSA-147/148/149 area comprises 3 of the 13 groundwater units at Redstone Arsenal and covers 8,792 acres in the central portion of the facility. These three groundwater units underlie 49 active surface media sites, plus another 33 which the Alabama Department of Environmental Management requires no further action for groundwater at this time. Chemicals released during historical activities at these surface media sites, including those within George C. Marshall Space Flight Center, contaminated groundwater within these groundwater units. The Army is responsible for groundwater outside the George C. Marshall Space Flight Center boundary as well as groundwater associated with MSFC-034.

RSA-147/148/149 groundwater has been characterized as a result of the groundwater unit investigation and numerous surface media site investigations. This report presents a comprehensive evaluation of the nature and extent of groundwater contamination within these groundwater units, focusing on six areas that are either not part of a surface media site investigation or will not be further addressed by ongoing surface media site investigations. However, this report integrates information from the RSA-147/148/149 Resource Conservation and Recovery Act facility investigation, from relevant surface media site investigations, and from other available sources. This report presents and discusses usable groundwater data collected from January 2007 through May 25, 2017.

The principal plume-forming contaminants present in RSA-147/148/149 groundwater are volatile organic compounds (chiefly trichloroethene, chlorobenzene, and carbon tetrachloride), pesticides, and explosive compounds, with additional impacts from semivolatile organic compounds and metals. Plumes of groundwater contamination within RSA-147/148/149 exist in shallow groundwater only, with only few, isolated contaminants identified in deep bedrock. All contaminants are delineated horizontally and vertically, and all plumes are stable or attenuating due to the combined effects of biodegradation, dilution, and dispersion.

Land-use controls are in place to prevent potable use of groundwater and provide management control over nonpotable uses of groundwater beneath Redstone Arsenal. Coupled with the existing site access control program, this interim remedial action protects workers and on- and off-post residents from exposure to facility-related contaminants in groundwater until final corrective measures are implemented for RSA-147/148/149.

The Army has determined that the investigation described in this report is adequate to determine the nature and extent of site-related chemicals in RSA-147/148/149 groundwater and meets the requirements of the Alabama Environmental Investigation and Remediation Guidance, the Alabama Risk-Based Corrective Action Guidance Manual, and the Alabama Hazardous Wastes Management and Minimization Act Hazardous Waste Storage Facility/Thermal Treatment/Solid Waste Management Unit Corrective Action Permit. The investigation is sufficient to determine that groundwater corrective measures are warranted and to support decision making for planning corrective measures.

The Army recommends that the Alabama Department of Environmental Management move RSA-147, RSA-148, and RSA-149 from Table VI.2 to Table VI.6 in the Alabama Hazardous Wastes Management and Minimization Act Hazardous Waste Storage Facility/Thermal Treatment/Solid Waste Management Unit Corrective Action Permit to facilitate the implementation of corrective measurements for groundwater. The Army recognizes that land-use controls may be a component of the corrective measures for RSA-147/148/149 groundwater.

## **1.0 Introduction**

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The U.S. Army is completing studies of the environmental impact of known or suspected waste sites at Redstone Arsenal (RSA), Madison County, Alabama, under the management of the U.S. Army Environmental Command. The Mission and Installation Contracting Command has contracted with Aptim Federal Services, LLC under Contract Number W91ZLK-09-D-0006 to perform environmental remediation, restoration, and program management services at RSA.

This report presents the results of the Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) for the RSA-147 groundwater unit (GW-03, Operable Unit [OU] 19), the RSA-148 groundwater unit (GW-04, OU-19) and the RSA-149 groundwater unit (GW-05, OU-19), hereafter referred to as RSA-147/148/149. The extent of RSA-147/148/149 is shown on Figure 1-1. The RFI was conducted under the RCRA Corrective Action Program (U.S. Environmental Protection Agency [EPA] ID # AL7 210 020 742) in accordance with the Alabama Hazardous Wastes Management and Minimization Act (AHWMMA) Hazardous Waste Storage Facility/Thermal Treatment/Solid Waste Management Unit (SWMU) Corrective Action Permit (hereafter referred to as the Permit) (last modified on February 15, 2017) (Alabama Department of Environmental Management [ADEM], 2017a).

### **1.1 Redstone Arsenal Location and Description**

RSA occupies approximately 38,172 acres (60 square miles) and is approximately 10 miles long from north to south and 6 miles wide from east to west (Figure 1-1). Development within RSA has largely centered on areas of higher elevation that hosted the historical production (and later disposal) of conventional and chemical munitions and, more recently, development and testing of missiles and rockets.

Wheeler National Wildlife Refuge was established in 1938 to provide protection for wildlife and encompasses 35,000 acres (55 square miles) on the Tennessee Valley Authority (TVA) Wheeler Reservoir. The U.S. Fish and Wildlife Service (USFWS) permits the Army to use 5,617 acres (9 square miles) in the central and southwestern portions of RSA along Wheeler Reservoir (the Tennessee River), Indian Creek, and Huntsville Spring Branch.

### **1.2 Redstone Arsenal Installation Restoration Program and SWMU Identification**

The U.S. Department of Defense (DoD) initiated a comprehensive environmental assessment program (the Installation Restoration Program [IRP]) to assess contamination that resulted from historical operations and disposal practices at DoD facilities and to determine cleanup measures. Sites determined to be contaminated as a result of historical operations and disposal practices are

defined as SWMUs. There are currently 82 SWMUs, or surface media sites, within the combined RSA-147/148/149 groundwater units. Surface media sites are distinguished as either National Aeronautics and Space Administration (NASA) George C. Marshall Space Flight Center (MSFC) environmental sites or Army surface media sites (Section 1.5.4). The term surface media site is used to define a SWMU or area of concern listed on the Permit that addresses unsaturated surface soil and subsurface soil, surface water, and sediment, as applicable, for investigative and restoration purposes. Surface media sites are also responsible for characterizing and delineating the nature and extent of groundwater underlying the site. Of the 82 surface media sites within the RSA-147/148/149 groundwater units, 49 sites are currently considered to be under active investigation and/or remediation. The 82 surface media sites are listed in Table 1-1 and shown on Figure 1-2. The primary goal of the IRP at RSA is to implement an approach for the evaluation and disposition of the SWMUs to protect public health and the environment. The IRP at RSA is administered by the Army Environmental Management Division.

### **1.3 The Watershed Investigation Approach**

Groundwater is the most mobile medium for dispersal of contamination at RSA. Once a contaminant has entered the groundwater system, advective transport coupled with dispersion may extend a contaminant plume well beyond the limits of the boundaries of the site in which the contamination originated. In some cases, an individual surface media site has contributed historically or is contributing currently to one or more plumes of groundwater contamination, which may be commingled with plumes from other, adjacent sites. Conversely, even though the groundwater beneath a site may exhibit contamination levels that pose unacceptable risk to human receptors, that surface media site may not be the source of the observed groundwater contamination. Groundwater is not bound by the limits of surface media site boundaries but is constrained by the groundwater watershed, defined by recharge and discharge divides. Therefore, plumes are also constrained within the groundwater watershed in which they occur.

Therefore, in 2002, with concurrence from the regulators, the Army defined broad groundwater units that are separate from but underlie the surface media sites. Collectively, the groundwater units span the extent of RSA (fence to fence) and are based on groundwater watersheds (Shaw Environmental, Inc. [Shaw], 2003a). Three extensive north-south-oriented watersheds have been defined at RSA: Betts Spring Branch, Indian Creek, and McDonald Creek-Huntsville Spring Branch (Figure 1-1). These watersheds originate well north of RSA and extend under RSA to the Tennessee River, which marks the southern boundary of RSA. Groundwater divides form localized flow regimes and act as sub-watersheds within the three larger watersheds that underlie RSA. Thirteen such sub-watersheds have been defined at RSA and form the basis for the 13 groundwater units designated on the Permit as sites with RSA site numbers (RSA-145

through RSA-157); these are shown on the inset map on Figure 1-1. RSA-147/148/149 lies in the central portion of RSA and spans portions of the central Indian Creek and eastern McDonald Creek-Huntsville Spring Branch watersheds.

To achieve short-term goals for groundwater remedies, an interim record of decision (IROD) for installation-wide groundwater at RSA was signed by the Army, EPA Region 4, and ADEM (Shaw, 2007a). The IROD and the land-use control (LUC) remedial design for installation-wide groundwater (Shaw, 2008a) present an interim remedial action consisting of LUCs to prevent potable use of groundwater and provide management control over nonpotable uses of groundwater beneath RSA. The goal of the interim remedial action, coupled with the existing RSA site access control program (U.S. Army Garrison-Redstone [Army], 2012) is to protect RSA workers and on- and off-post residents from exposure to contaminants in groundwater attributable to RSA until final corrective measures are in place for groundwater units.

The groundwater units were intended to accelerate investigation and remediation of the overlying surface media sites. The surface media site investigations assess the nature and extent of contamination in the unsaturated (vadose) zone, including surface and subsurface soils, the potential for receptor exposures, leaching of contamination to groundwater, and runoff to surface water and sediment. The surface media site investigations are responsible for characterizing and delineating groundwater to identify releases and assess the nature and extent of impacts to groundwater. Groundwater unit investigations address the nature and extent of groundwater contamination on the groundwater unit scale, integrating impacts from discrete and commingled plumes from multiple sources (surface media sites).

#### **1.4 Integrator Operable Units**

Integral to the watershed approach is the understanding that wetlands and surface water features at RSA are receptors for contaminant discharge from surface media sites (via surface runoff) and groundwater (via discrete spring or diffuse seepage discharge), serving as integrators from one or both of those pathways. A total of 11,174 acres (18 square miles) within RSA are currently included in the Integrator Operable Unit (IOU) boundary, of which 10,015 acres (16 square miles) are mapped as wetlands based on USFWS National Wetland Inventory mapping (Shaw, 2010a). Wetlands and surface water features occupy nearly 30 percent of the surface area of RSA.

In 2009, the Army produced a protocol document that introduced the defining features of a potential wetland IOU and delineated the extent of the area in which the IOU may be defined (Shaw, 2009a). A total of 12 geographic subunits were recommended in the subsequent *Final Installation-Wide Strategy for Cleanup of Impacted Wetlands* (Shaw, 2010a). Twelve IOUs are

listed on the Permit, four of which (shown in bold type) lie within or partially within the RSA-147/148/149 groundwater units (Figure 1-2):

<u>SWMU</u>	<u>Description</u>
IOU-1	Huntsville Spring Branch east of McDonald Creek
<b>IOU-2</b>	<b>Huntsville Spring Branch east of Patton Road</b>
<b>IOU-3</b>	<b>Huntsville Spring Branch, Patton Road through Olin</b>
<b>IOU-4</b>	<b>Huntsville Spring Branch, Indian Creek Confluence</b>
IOU-5	McDonald Creek
<b>IOU-6</b>	<b>Indian Creek</b>
IOU-7	Southeastern Boundary System
IOU-8	McKinley Range
IOU-9	Southwest Area
IOU-10	Bradford Sinks
IOU-11	Tennessee River East
IOU-12	Tennessee River West

The Army's strategy for cleanup of impacted wetlands pursuant to the Permit relies on the integration of actions within the groundwater, surface media, and wetland IOU sites. This approach involves cleaning up primary sources of contamination identified at surface media sites and addressing secondary sources and plumes in groundwater units to prevent ongoing transport of contaminant to wetlands. In addition, potential corrective measures that are needed to address impacts caused by groundwater discharging to surface water and sediment will be performed during the corrective measures for the groundwater units, which in this case are RSA-147, RSA-148, and RSA-149.

### **1.5 RSA-147/148/149 Site Description**

Collectively, RSA-147/148/149 occupies approximately 8,800 acres in the central portion of RSA and includes land used for industrial purposes (research, manufacturing, administration, and waste disposal) and pastures, forest, and wetlands. Also within the study area is the NASA MSFC, where space flight research has been conducted since 1960. Also included within RSA-147/148/149 are NASA environmental site OU-3 and the Olin Consent Order site (RSA-101) (Figure 1-3). The RSA-147/148/149 area is generally bounded to the west by Indian Creek and associated wetlands and to the south by Huntsville Spring Branch and associated wetlands. A portion of the Wheeler National Wildlife Refuge lies in the southern portion of RSA-147/148/149, as shown on Figure 1-1.

#### **1.5.1 RSA-147**

RSA-147 covers approximately 1,300 acres in the central portion of RSA, north of Huntsville Spring Branch, west of Patton Road, east of Mills Road, and south of Neal Road. RSA-147 encompasses three former production areas and several disposal sites (RSA-054/055 and

RSA-060). Three major areas of former operations at RSA-147 include the former Nashville, Chattanooga and St. Louis classification yard; the former Plant Area No. 2; and the DDT Manufacturing and associated liquid caustic plant, chlorine plant, and brine processing facilities (collectively comprising the RSA-117 area). Other SWMUs in the groundwater unit include support facilities such as underground storage tanks, wash racks, and oil/water separators. The former classification yard (RSA-223) and a former open storage/holding area (RSA-224) have achieved no further action (NFA) at this time as identified on Table VI.3 of the Permit. No further discussion of these sites is warranted. The former Plant Area No. 2 (RSA-122) was located south of Martin Road, also on relatively level ground resulting from considerable cut and fill of soil during construction.

Prior to construction of the former Plant Area No. 2 in 1941 and 1942, RSA-147 was used for agricultural purposes. The classification yard was completed in late 1941 and had seven tracks with a 116-car capacity. The classification yard was initially important as an area for the receipt of inbound items such as heavy construction equipment and supplies, coal, fuel oil, and various other products. An open storage area immediately to the south of the former classification yard was evident in 1943. This area was involved in the sorting and storage of various items, either from inbound or awaiting outbound shipment.

The former Plant Area No. 2 (RSA-122) included the following process components:

- One chlorine manufacturing plant (within RSA-117)
- One thionyl chloride manufacturing plant (within RSA-117)
- One carbonyl iron manufacturing plant (RSA-119 NFA site)
- One mustard manufacturing plants (RSA-238)
- One incendiary oil bomb filling plant(RSA-252)
- One phosgene manufacturing plant (RSA-251 NFA site)
- Four lewisite manufacturing lines (RSA-122)
- One arsenic trichloride (AT) manufacturing plant (RSA-122).

Additional buildings in former Plant Area No. 2 included a steam plant, offices, an analytical laboratory, fire house, maintenance shop, cafeterias, warehouses, and change houses.

Two mustard manufacturing plants (one in RSA-147 and the other in RSA-148) were constructed in 1942. Each plant consisted of a sulfur monochloride building, an ethylene generator building, and a mustard reactor building. Each plant was designed to produce 24 tons of mustard daily; however, actual production was approximately 40 tons daily. Production of mustard officially ceased in May 1943.

In support of mustard production in Plant Area No. 2, one chlorine plant was constructed. The plant could produce 50 tons of gaseous chlorine or 45 tons of liquid chlorine and 56 tons of 50 percent caustic soda per 24 hours. Chlorine was a necessary ingredient for the manufacture of mustard gas. Preliminary operations began in May 1942 and continued through July 1945.

The only phosgene plant at Huntsville Arsenal was located in the former Plant Area No. 2 and operated from February 1944 to January 1945. The plant included a carbon monoxide generating plant, a container filling shed, a catalyzer building, various storage tanks, and an office building. A phosgene filling plant situated immediately adjacent to this complex had six filling stations, each capable of filling 40 bombs per shift. Filling operations began in April 1944 and continued until the supply of phosgene was depleted in January 1945.

A thionyl chloride plant was also constructed in this area in 1943. Its primary purpose was to supply a drying and chlorinating agent for the treatment of crude lewisite to decrease sludge formation. The plant could produce as much as 5 tons of thionyl chloride per day. Production began in March 1943 and was discontinued in October 1943.

Another plant contributing to the manufacture of lewisite was the AT plant. This complex consisted of an AT reactor building, a sulfur monochloride manufacturing plant, and a sulfur dioxide disposal system. The plant had a capacity of approximately 30 tons per day. Operation began in March 1943 and continued until November 1943, when it was placed on standby.

Four lewisite manufacturing plants were originally intended for Plant Area No. 2 (RSA-122). Plant Nos. 5 and 6 were completed except for minor items of equipment and were never activated. Plants 3 and 4 began operation in May 1943; however, Plant 4 was not operated continuously because of a shortage of AT. All manufacturing operations were discontinued in October 1943. In association with lewisite manufacturing operations, arsenic-based wastes were disposed in pits/lagoons within the manufacturing area. Currently, the former lewisite manufacturing area contains a few buildings; however, it is largely open, partly tree covered, and vegetated with grass. None of the production buildings from Lewisite Plants 3, 4, and 5 exists today; however, several of the buildings associated with Plant 6 are currently in use.

An iron carbonyl plant was built by the military in 1943 and 1944 but was put on standby status after the initial demonstration of the manufacturing process. General Aniline & Film Corporation leased the plant in 1947 and began manufacturing iron carbonyl. In 1993 and 1994, the plant was taken over by International Specialty Products, which currently operates the plant. Operations and manufacturing processes have remained practically unchanged since inception.



In 1945, activities in the former Plant Area No. 2 were placed on standby status. In 1946, the chlorine manufacturing plant and other buildings in the area were leased to the Solvay Process Division of Allied Chemical and Dye Corporation, which was an intermediate chemical manufacturer for the pesticide DDT. In 1947, the Calabama Chemical Corporation (DDT manufacturer) and John Powell Chemical Company (DDT blending, processing, formulating, and bagging) began production of DDT. In 1954, Olin Mathieson Chemical Corporation acquired these companies and continued to produce DDT until 1970. In November 1971, the plant closed, and in early 1972, the DDT plant was demolished by the Army (Shaw, 2005a).

### **1.5.2 RSA-148**

RSA-148 covers approximately 3,500 acres in the central portion of RSA, north of Huntsville Spring Branch, west of Mills Road, east of Dodd Road, and south of Neal Road. The current predominant features in RSA-148 are the ABMA Information Processing Center (Building 4488), Redstone Test Center, AMC (Building 4500), Richard Shelby Complex—Center for Missile Intelligence, the Missile Defense Agency (Building 4505), and the cargo helicopter project offices for PEO Aviation.

Four major areas of former operations/activities within RSA-148 include the former Lewisite Plants 1 and 2 (part of former Plants Area No. 1), three sanitary landfills (RSA-010, RSA-053, and RSA-060) in the southern portion, a demilitarization and disposal site, and a salvage yard. The former Lewisite Plants 1 and 2 (RSA-183) and the associated capped arsenic waste disposal ponds (RSA-049) were located north of Digney Road on relatively level ground and are existing environmental sites. The sanitary construction and demolition (C&D) landfills are located immediately east of the MSFC East Test Stand area (RSA-010). The former chemical warfare materiel demilitarization and disposal site is east of Dodd Road, south of the MSFC East Test Stand, and north of Huntsville Spring Branch; this site is identified as RSA-061. The former salvage yard was located on the northwestern corner of Martin and Mills Roads on relatively level ground (Shaw, 2005b).

### **1.5.3 RSA-149**

RSA-149 covers approximately 4,000 acres in the western-central portion of RSA, north of Huntsville Spring Branch, west of the MSFC boundary and Rideout Road, and east of Indian Creek (Figure 1-1). The predominant features in RSA-149 are MSFC, Indian Creek, Huntsville Spring Branch, and associated wetlands.

Aside from NASA's operations within MSFC, there are four major areas of former Army operations and activities within RSA-149:

- An abandoned drum disposal area (MSFC-002)
- The former Sewage Treatment Plant No. 3 (RSA-009)
- The former chemical (mustard) production and filling area in the northeastern portion of MSFC (MSFC-034)
- Two chemical warfare materiel demilitarization and disposal areas (RSA-052 and RSA-109) on the north side of Huntsville Spring Branch and RSA-063 and RSA-264 on the south side of Huntsville Spring Branch.

The abandoned drum disposal area is located on the western edge of MSFC and extends into RSA. The former Sewage Treatment Plant No. 3 is an environmental site located on the south side of Martin Road, just west of the MSFC boundary along the eastern bank of Indian Creek. One of the two disposal sites is located west of the MSFC West Test Area and Dodd Road and bounded by Wheeler National Wildlife Refuge to the northwest and south. The second disposal area is identified as a suspected staging area for mustard gas operations and/or a disposal site for debris resulting from the demolition of chemical plants. This area is located off a former railroad spur north of Huntsville Spring Branch and west of Dodd Road.

#### **1.5.4 George C. Marshall Space Flight Center**

NASA's MSFC is located on approximately 1,840 acres in the central portion of RSA. Approximately one-fourth of the MSFC footprint lies within RSA-148; the remainder is located in RSA-149 (Figure 1-3). In 1949, RSA's mission was changed from production of conventional and chemical munitions to research and developments of rocketry and guided missile systems. In 1960, civilian rocketry and missile activities were transferred to NASA's MSFC. The Army granted irrevocable use and occupancy to the land and facilities known as MSFC to NASA for a term of 99 years beginning on July 1, 1960 and ending on June 30, 2059. MSFC is NASA's principal propulsion development center. The area known as MSFC has been used to develop, test, and manufacture space vehicles and components. MSFC sites that have transferred to the Army are listed in the RSA Permit.

**Operable Unit 3.** NASA is conducting remedial investigation (RI)/feasibility study investigations under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and has established OU-3 to include all groundwater beneath MSFC and the adjacent areas believed to be affected by groundwater beneath MSFC. The OU-3 boundary extends to just beyond the downgradient inland surface water systems of Indian Creek and

Huntsville Spring Branch to the south and west (Figure 1-3). The eastern and northern boundaries of OU-3 are more arbitrary, with the eastern boundary representing the approximate extent of contaminated groundwater believed to affect off-site areas and the northern boundary general coinciding with the northern MSFC boundary (CH2M Hill, 2012a).

NASA has identified five major shallow groundwater plumes originating from source areas at MSFC. These plumes (Northwest, Northeast, Central, Southeast, and Southwest) are composed mainly of chlorinated volatile organic compounds (VOC), with trichloroethene (TCE) and its degradation products the most common and widespread constituents. Multiple source areas are associated with each plume (Table 1-2). The plumes have migrated downgradient to the east-southeast, south, southwest, and west in the shallow groundwater and/or merge into the deep bedrock groundwater. Both shallow and deep groundwater eventually discharge at surface water and spring locations in the wetland system to the south and west, which represents a broad groundwater discharge zone. The environmental restoration program at MSFC is conducted under CERCLA. Further discussion of the NASA plumes and source areas is described in greater detail in the NASA RI report (CH2M Hill, 2012a).

In 1994, the Army and NASA entered into a memorandum of agreement (MOA) detailing the responsibilities of Army and NASA associated with environmental investigation requirements under CERCLA for potential contaminant sources within the NASA boundary. Based on the RCRA facility assessment conducted by EPA in 1989, SWMUs that were determined to be the responsibility of the Army were assigned an “RSA” designation and SWMUs that were determined to be the responsibility of NASA were assigned an “MSFC” designation. Based on subsequent modifications to the MOA, the responsibilities for some sites have shifted from NASA to the Army and vice-versa via several amendments to the MOA. MSFC sites that are currently the responsibility of the Army are listed in the Permit (ADEM, 2017a).

As part of MSFC’s Federal Facilities Agreement (FFA), NASA is responsible for all groundwater within the MSFC boundary (including under Army surface media sites). Under MSFC’s FFA, they also conduct routine monitoring in off-site areas. In a supplement to the 1994 MOA, Army will be responsible to investigate all media at MSFC-034 including groundwater, and has taken on the responsibility to perform the groundwater corrective measures for this site. In accordance with MSFC’s FFA, final responsibility for MSFC’s OU-3 remains with NASA. The extents of MSFC and MSFC-034 are shown on Figure 1-3.

#### **1.5.5 Olin Corporation Consent Decree Site**

In 1947, the Calabama Chemical Corporation (DDT manufacturer) and John Powell Chemical Company (DDT blending, processing, formulating, and bagging) began production of DDT. In

1954, Olin Mathieson Chemical Corporation acquired these companies and continued to produce DDT until 1970. In November 1971, the plant closed, and in early 1972, the DDT plant was demolished by the Army (Shaw, 2005b).

Wastewater discharged from the DDT manufacturing plant from 1947 to 1970 resulted in extensive DDT contamination in Huntsville Spring Branch and Indian Creek. The most recent estimate of the DDT contamination in stream sediments is 417 tons, 94 percent of which is located between Huntsville Spring Branch miles 2.4 and 5.57 (EPA, 1986).

On May 31, 1983, the United States District Court for the Northern District of Alabama issued the consent decree that governed the development and implementation of remedial action for DDT contamination in the Huntsville Spring Branch-Indian Creek System. The purpose of the consent decree was to isolate DDT in the Huntsville Spring Branch-Indian Creek system from people and the environment and minimize transport of DDT out of the Huntsville Spring Branch-Indian Creek system. The consent decree required the Olin Corporation to develop and implement a remedial plan and conduct monitoring of fish, groundwater, surface water, sediment, and sediment transport. Remedial actions conducted by Olin included rerouting of Huntsville Spring Branch to bypass the most heavily contaminated areas and burial in place of contaminated sediments.

The location of the Olin Consent Decree site (RSA-101) is shown on Figure 1-3.

### **1.6 Groundwater Responsibility Information Matrix**

The Groundwater Responsibility Information Matrix (GRIM) is the Army's mechanism for ensuring that corrective measures properly address contaminants in groundwater at RSA. For each surface media site, the GRIM database documents any relevant chemicals of concern (COC) for groundwater and records the assignment of responsibility for groundwater corrective measures. COCs and chemicals of analytical concern (COAC) are preliminary until ADEM approves the associated RFI report. The GRIM is critical for Army planning efforts and completing RFI and corrective measures study reports. The RFI completion status for each surface media site within the RSA-147/148/149 groundwater units is presented on Figure 1-4.

**Investigation/Delineation Strategy.** For sites listed in the Permit as requiring an RFI, the responsibility for delineation of surface media site-related groundwater contamination typically lies with the surface media sites. The RSA-101 area is responsible for its groundwater delineation and NASA is responsible for investigation and cleanup of all groundwater within the MSFC or at locations with contamination originating from MSFC. The groundwater units are responsible for groundwater contamination relating to certain sites where no action is required

for soil as listed on Table VI.6 of the Permit and will investigate groundwater beneath Permit-regulated sites, and sites functioning under the Operational Range Assessment Program. Table 1-3 summarizes the delineation responsibility for all SWMUs within RSA-147/148/149. Of the 49 active SWMUs within RSA-147/148/149, 34 are responsible for groundwater delineation within these groundwater units (Table 1-1). The groundwater units are responsible for groundwater characterization at the remaining 15 SWMUs. Because of the density of surface media sites undergoing investigation or cleanup within these groundwater units, there are relatively few areas of contaminated groundwater that are the responsibility of the groundwater units. The current assignment of groundwater contaminant delineation responsibility by surface media site is summarized in Tables 1-1 and 1-3 and graphically presented as Figure 1-5.

This RFI report presents data from groundwater samples and other environmental media collected from within the RSA-147/148/149 groundwater unit boundaries, including data from the various surface media site investigations as well as data obtained specifically from investigation of the groundwater units. It is not the intent of this RFI to reinterpret data already presented in the various surface media site RFI reports but to use those data, as necessary, to bound contamination identified within areas of groundwater unit responsibility. Further explanation of this contaminant delineation strategy is presented in Chapter 4.0.

**Groundwater Cleanup Strategy.** Typically, the Army intends that cleanup actions occur under the groundwater unit. For example, groundwater actions have been assigned to the groundwater unit by the Army when contamination is commingled among sites or the groundwater contaminants found at a surface media site are ubiquitous throughout the region of the associated groundwater unit and present at low concentrations. The Army believes the best technical and management approach is to address these action on a broader scale than at the surface media site level and intends to address pervasive, ubiquitous, and low-concentration contamination on the basis of the groundwater unit in order to maximize the effectiveness and efficiency of the selected remedy.

Where releases to groundwater at surface media sites clearly constitute source material which poses an ongoing release from the source to groundwater, the Army intends to expedite the cleanup actions at these sites and perform corrective measures as a surface media site responsibility.

### **1.7 Purpose and Objectives**

The RSA-147/148/149 groundwater units are listed as SWMUs requiring RFIs in Table VI.2 of the Permit. As described previously, RSA-147/148/149 contain surface media SWMUs that may have been sources of contamination to groundwater and, with exceptions, are responsible for

delineating the extent of that groundwater contamination. The objectives of this RFI are as follows:

- Identify the concentrations of hazardous constituents within the areas of groundwater unit responsibility.
- Delineate the nature and extent of contamination not addressed by surface media site RFI reports.
- Provide the information needed to determine whether corrective measures are needed to address groundwater contamination not addressed by surface media sites.

Surface soil and subsurface soil data have been and will continue to be reported as part of surface media site SWMU investigations and are not addressed within the RFI for RSA-147/148/149. All of the surface media SWMUs have been characterized to some extent. Those that serve as source areas are evident as groundwater hot spots that represent locations of contaminant releases to groundwater from specific surface media SWMUs. This RFI focuses on defining the nature and extent of groundwater contamination that is not the responsibility of an individual surface media site. Data from other media, including surface water and sediment, are presented in this RFI but only to evaluate the impact on them as a direct result of groundwater discharge.

This RFI addresses ADEM requirements identified in the Alabama Environmental Investigation and Remediation Guidance (AEIRG) (ADEM, 2017b) and the Alabama Risk-Based Corrective Action (ARBCA) guidance manual (ADEM, 2017c).

### **1.8 RFI Report Organization and Overview**

This RSA-147/148/149 groundwater RFI report is presented in nine chapters (including this introduction) and a series of supporting appendices and attachments. The appendices and attachments are intended to capture details of specific information and data and/or to support the findings summarized herein.

Chapter 2.0 presents a summary of available information used in this RFI, including key historical and recent sources of information and data relevant to the RFI objectives stated previously. The 2010 sitewide seismic survey report is provided in Appendix A.

Chapter 3.0 presents the physical and hydrogeological setting of RSA-147/148/149, with emphasis on information relevant to understanding the nature and extent of chemicals detected in groundwater and their fate and transport. Chapter 3.0 describes the physical nature of the aquifer underlying RSA-147/148/149 and the groundwater flow system. Pertinent monitoring well and

borehole characterization data are provided in Appendices B and C. Water level data are provided in Appendix D.

Chapter 4.0 summarizes the data evaluation methodologies used, including a data usability evaluation and site-to-background comparison.

Chapter 5.0 presents the nature and extent of chemicals detected in groundwater within areas of groundwater unit responsibility. Analytical data for all samples collected within the RSA-147/148/149 groundwater units, as well as the associated quality control summary report, is provided as Appendix F. For target analyte list (TAL) metals, a groundwater unit-wide site-to-background comparison for groundwater and surface water is provided as Appendix G.

Chapter 6.0 addresses the fate and transport of groundwater unit-responsible chemicals in RSA-147/148/149 groundwater and a description of processes acting on the groundwater contaminants that relate to fate and transport (including biodegradation). Concentration trend plots are provided in Appendix H and Chapter 6.0, and a biodegradation potential evaluation is provided in Appendix I.

Chapter 7.0 presents the results of an ARBCA preliminary screening level (PSL) risk assessment to document the potential risks to human health and ecological receptors from exposure to groundwater, soil vapors emanating from groundwater, and surface water impacted by groundwater. The detailed assessments are presented in Appendices J and K.

Chapter 8.0 provides an integrated summary of the key findings and conclusions from the previous sections and recommendations based on conclusions from this RFI.

Chapter 9.0 lists references consulted in preparing this report.

Attachment 1 is a list of acronyms and abbreviations used in RSA documents. Attachment 2 contains records from the field investigations.

## **2.0 Summary of Environmental Investigations**

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Investigation of the RSA-147/148/149 groundwater units dates back to 1978 (RSA-147 and RSA-148) and 1988 (RSA-149), when the first monitoring wells were installed and sampled. This chapter describes the data collection efforts that contribute to and support the RSA-147/148/149 RFI. The relevant investigations are summarized in approximate chronological order.

### **2.1 Sitewide Karst Hydrogeologic Investigation**

In 1999, the Army contracted Shaw to perform a karst hydrogeologic investigation of the entire RSA facility. Over a three-year period, the following tasks were performed:

- Compilation of a detailed inventory of karst surface and subsurface features. The former was completed through stereoscopic analysis of historical, pre-site development and post-development aerial photographs to identify sinkholes, many of which are now masked by subsequent development. The latter included review of all available subsurface boring logs from environmental and geotechnical/engineering design borings to document the occurrence of karst features in the subsurface. Maps of caves were also compiled and presented.
- Compilation and integration of all available groundwater hydraulic data.
- Collection of sitewide synoptic water level measurements for two distinct seasons and generation of potentiometric maps for the entire RSA site.
- Acquisition and integration of available surface water stage and discharge data.
- Borehole flowmeter surveys in existing wells to aid in producing potentiometric maps and assessing potential watershed boundaries.
- Instrumenting and continuous monitoring of select wells, springs, and surface water features to evaluate the dynamics of the karst aquifer system and interactions with surface water bodies. Eight wells (F53-RS138, F53-RS139, F53-RS335, F53-RS179, F53-RS277, F53-RS275, and F53-RS752, and H52-RS752 and H52-RS835) and three springs (RSP-1196, RSP-1326, and RSP-0830) were instrumented and monitored for 9 to 11 months in 1999 and 2000 within RSA-147/148/149. Continuous monitoring locations are shown on Figure 2-1.
- Compilation and integration of all dye tracing results performed within and near RSA.
- Completion of a high-resolution aerial thermal infrared survey of the entire installation and surrounding parcels which served to identify more than 2,000 discrete points of groundwater discharge (springs and seeps) sitewide, accompanied by a field confirmation effort and spring sampling program. A total of 358 apparent springs



were identified within RSA-147/148/149. Nine perennial springs (RSP-0373, RSP-0375, RSP-0694a, RSP-0772a, RSP-0792, RSP-0824a, RSP-0830, RSP-1020, and RSP-1026) within RSA-147/148/149 were sampled in July 1999. Three of these springs were resampled in March 2000 (RSP-0375, RSP-0830, and RSP-1026).

- Development of conceptual models describing the hydrogeologic framework of RSA based on the elements described above.

The findings and interpretations of these activities were presented in the *Site-Wide Karst Hydrogeologic Investigation Phase I Report of Findings* (Shaw, 2003a), which provides information that supports the identification and evaluation of potential contaminant transport pathways. The findings of the karst investigation highlight the need to characterize groundwater contamination and make remedial decisions for groundwater on a large-scale, watershed basis. The groundwater unit boundaries (including RSA-147/148/149) were established to address that need, and those boundaries were based on all available information, as synthesized by the karst investigation.

## **2.2 Dye Trace Studies**

Four dye trace studies were conducted within RSA-147/148/149 from 1992 to 2002. Table 2-1 provides a summary of the scope and results of the dye trace studies. The scope of the studies is described in Sections 2.2.1 through 2.2.4, with brief discussion of the results. The implications of those results are discussed further and presented in graphic form in Chapter 3.0.

### **2.2.1 1992 GSA Dye Trace**

In 1992, the Geological Survey of Alabama (GSA) conducted a limited dye trace in RSA-149 (Rheams et al., 1994). One pound of fluorescein dye was injected on May 7, 1992 into well MC-MW-51D, located within the former MSFC water treatment plant site. Post-injection monitoring was conducted at four locations every five days for a total of 25 days following the injection. Monitored locations included Matthews Cave (which lies several miles to the west in RSA-153, upgradient of the study area), Indian Creek above and below Martin Road, and NASA Spring (also known as RSP-0694). Dye was detected only in Indian Creek below Martin Road and not in NASA Spring, which discharges to the creek immediately upstream of the monitored location.

### **2.2.2 1996 GSA RSA-010 Dye Trace**

The GSA performed two dye traces in 1996, this time for the Army at the RSA-010 landfill site (GSA, 1996). Initially, 1 pound of fluorescein was injected in well F10-RS177, an interface well (screened interval straddles the overburden-bedrock contact), on April 12, 1996. Six adjacent wells (F10-RS086, F10-RS091, F10-RS175, F10-RS178, and extraction wells F10-RS488 [EX01] and F10-RS490 [EX03]) were monitored at 5-day increments for a period of 25 days

after the injection was complete. No fluorescein was detected in any of the monitored locations during the monitoring period.

A second injection was completed in well F10-RS178, the overburden well paired with F10-RS177. In this case, 1 pound of eosine was injected on April 17, 1996. The same post-injection monitoring network was used. Monitoring was performed at 5-day increments for a total of 20 days. Again, no dye was detected in any of the monitored locations within the monitoring period.

### **2.2.3 NASA MSFC Dye Trace**

From 1997 through 1999, CH2M Hill performed a comprehensive and iterative dye tracing program on behalf of MSFC involving a total of 14 separate dye injections. This tracing involved injection of five distinct dyes (fluorescein, sulforhodamine B, rhodamine WT, eosine, and Red-28) at 12 injection locations. Multiple injections were performed in several of the wells using different dyes in order to confirm results. Post-injection monitoring was conducted at up to 20 locations (springs and wells) for each injection, using a graduated frequency post-injection monitoring approach and a post-injection monitoring period that ranged from 30 to 856 days (2.3 years). Additional grab samples were collected from specific locations.

The NASA dye trace results are published as Appendix B of the draft final OU-3 RI report (CH2M Hill, 2012a).

### **2.2.4 Central Redstone Dye Trace Study**

In 2002, the Army performed a series of dye traces within the RSA-147/148/149 groundwater units (Shaw, 2004a). The scope of work included three principal components: site characterization activities completed prior to the dye tracing, the dye tracing itself, and completion of a reflection seismic survey and associated tasks. Six boreholes were drilled to a depth of approximately 150 feet below ground surface (bgs) and characterized with open hole logs (including televiewer) and hydrophysical testing. The upgradient three boreholes were used as injection locations (Z-RS1237, Z-RS1238, and Z-RS1239). The downgradient boreholes (Z-RS1232, Z-RS1233, and Z-RS1235) were completed as multizone, nested wells. The scope of the seismic surveys is described in Section 2.3.

The dye trace was initiated in February 2002 and completed in December 2002. The scope of Army dye tracing within RSA-147/148/149 is summarized in Table 2-1. The dye tracing consisted of five injections using distinct dyes. An initial set of concurrent injections was performed, followed by two secondary injections.

Initial injections were conducted on April 7 and 8, 2002 and consisted of injecting dye into the three newly installed 150-foot-deep open bedrock boreholes:

- D&C Red 28 (10 pounds) plus the optical brightener Tinopal CBS-X (30 pounds) injected into INJ-1 (Z-RS1237)
- Sulforhodamine B (20 pounds) injected into INJ-2 (Z-RS1238)
- Eosine (20 pounds) injected into INJ-3 (Z-RS1239).

Subsequent secondary injections were made into two existing bedrock wells using two additional distinct dyes:

- FD&C Red 3 dye (20 pounds) injected into well IWDY-002 on July 16, 2002)
- Fluorescein dye (20 pounds) injected into well F54-RS203 on July 17, 2002.

Pre-injection background dye characterization and post-injection monitoring were conducted at 312 locations, including 239 monitoring wells, 43 perennial springs, 28 surface water monitoring stations, and 2 sumps. All 312 locations were monitored over 16 sampling events through December 27, 2002. The pre-injection background characterization was conducted after completion of NASA's dye tracing and served to provide additional insight regarding positive dye presence at locations monitored as part of the NASA effort.

Dye tracing results are listed in Table 2-1 and discussed in Chapter 3.0.

### **2.3 Seismic Profiling**

Faulting is a key component of the conceptual site model (CSM), and faults are primary targets for drilling bedrock wells. Faults observed on separate seismic survey lines have been correlated to project faults across multiple lines and map the geologic structure. Targeting faults in drilling provides increased confidence of encountering subsurface features (karst voids, solutionally enlarged fractures, and open fractures) that control groundwater flow. Consequently, seismic surveys have emerged as a key tool for identifying the location of "smart" wells, consisting of paired, clustered, nested, or other multizone completion wells targeting all of the observed flow zones to depth.

Seismic surveys relative to RSA-147/148/149 were completed as two distinct projects. Initially, a total of 13.56 miles of reflection seismic survey data were acquired along nine lines within RSA-147/148/149 in 2002. Additionally, to corroborate the reprocessed seismic data, a total of 46 existing bedrock wells were gamma-ray logged in November 2003 (as part of the central RSA dye trace project). This provided structural formation tops with which to calibrate the seismic data.

To provide a more sitewide perspective and support the RFIs within each of the groundwater units, in April 2010, Shaw contracted Excel Geophysical Services (Excel) to conduct sitewide reflection seismic surveys. Excel teamed with Bird Seismic, Golder Associates, and ExplorTech, LLC (ExplorTech) for this project. Bird Seismic and Golder Associates collected the data, Excel processed the data, and ExplorTech provided processing quality control and interpretation of the data.

From May through June 2010, nearly 70 miles of reflection seismic data were acquired across RSA and integrated with previously acquired seismic surveys (in RSA-146, in RSA-147/148/149, and along the northern RSA boundary in RSA-150 and RSA-145). Approximately 25.61 miles of reflection seismic data were acquired on land along 13 lines that extend through the various groundwater units. A total of 5 miles of reflection seismic survey data were acquired along three lines within RSA-147/148/149 in 2010. Additional seismic data acquired just beyond the boundary of RSA-147/148/149 contributes to the mapping of structure within the units. The 2010 seismic lines intersect or overlap the previously surveyed seismic lines, providing for correlation between the two surveys. Figure 2-2 shows the seismic survey lines.

As part of this effort, Excel and ExplorTech integrated all of the available seismic data to develop facility-wide structure maps, mapping the structure at the top of the Chattanooga Shale, the primary correlable shallow reflector. All available formation top information from deep boreholes within RSA-147/148/149 and across RSA were integrated with the seismic data to develop the structure contour mapping.

Deep drilling completed as part of the RSA-147/148/149 RFI provided additional Chattanooga Shale elevation data. The structure contour map presented in this report reflects revisions to the 2010 Excel/ExplorTech mapping to accommodate this new information.

## **2.4 Basewide Spring and Seep Sampling**

A total of 106 springs and seeps across RSA were sampled in March and April 2002, and the results are reported in the *Base-wide Groundwater Spring and Seep Sampling Report of Findings* (Shaw, 2004b). Eight springs were sampled within RSA-147/148/149 as part of that effort (RSP-0694a, RSP-0772a, RSP-0792, RSP-0802, RSP-0824a, RSP-0830, RSP-1020, and RSP-1026). Spring samples were analyzed for TAL metals, explosive compounds, pesticides, VOCs, and semivolatile organic compounds (SVOC). Select samples were also analyzed for chemical agents.

## **2.5 Potential Source Area Investigation**

A comprehensive potential source area (PSA) investigation was conducted in 2004 and 2005 within RSA. Collectively, these investigations comprise a fence-to-fence inventory of PSAs at RSA and ensure that all PSAs are integrated into the Army's cleanup program. The PSA investigations included an exhaustive compilation and review of historical records, including archival aerial photography, interviews with former employees, building inventories, and archival engineering architectural design drawings. Following review of the archival records, each PSA (typically a specific building or area identified via aerial photographs) was evaluated to determine if it a) is located within a known/existing CERCLA or RCRA site, b) has sufficient characterization data to document whether it is (or was) a source of contamination, or c) does not warrant further investigation based on the operational history and other information. A visual site inspection (VSI) was conducted for each PSA that did not meet these criteria. The VSIs consisted of site visits to document visible features through notes, photographs, and geographic positioning. Specific effort was made to document potential processes, pathways, and locations where releases may have occurred. The VSI information was integrated with the archival information to further refine the list of PSAs. A limited site assessment (LSA) was conducted for each PSA where historical use and/or VSI observations indicated a potential for a contaminant release and where data were either nonexistent or insufficient to assess whether a release has actually occurred. The LSAs were intended only to confirm or rule out the presence of contamination. The scope was limited to vadose soil profiling and groundwater grab sampling at biased locations where releases are most likely to have occurred. Biased sampling locations included features such as sumps, drainage discharges, process/storage areas, disposal areas, and loading docks (Shaw, 2008b).

For organizational purposes, RSA-147 was divided into four PSA groups (147-PS-01 through 147-PS-04) based on historical operations and geographic proximity, while RSA-148 and RSA-149 were single PSA groups (148-PS-01 and 149-PS-01). Over the three groundwater units, a review of archival information regarding historical operations was completed for 129 PSAs. Existing environmental data were integrated into the evaluation to determine which PSAs warranted further investigation through an LSA or as a CERCLA site. For 56 PSAs with inadequate information to make a determination, VSIs were performed between February 2004 and August 2004 to assess whether, how, and where contaminant releases may have occurred. Information obtained during the archive search and the VSIs was integrated and reviewed to identify those PSAs where analytical data would be necessary to make a final determination. LSAs were performed at 27 PSAs between May 2004 and January 2005 to confirm or rule out the presence of a contaminant source (Shaw, 2004c; 2005a).

Each LSA filled data gaps by collecting biased samples of environmental media (soil, sediment, surface water, and groundwater) at locations selected to address the most likely release point(s) (e.g., sumps, drainage discharges, process/storage areas, disposal areas, and loading docks) and analyzing them for contaminants that would indicate impact from historical activities. The results of the PSA investigations were presented in the PSA reports for RSA-147 (Shaw, 2004c) and RSA-148/149 (Shaw, 2005b). Based on the results, some PSAs became CERCLA or RCRA sites, while no further investigation was necessary for others.

As part of the PSA effort, a total of 85 screening-level direct-push technology (DPT) samples were collected within RSA-147/148/149. Available data from the PSA effort have been integrated into the RSA-147/148/149 RFI.

## **2.6 MSFC Investigations**

MSFC is contained within RSA-148 and RSA-149. NASA has conducted extensive characterization of MSFC surface media source sites and groundwater. Additionally, NASA has performed long-term monitoring (LTM) of wells, springs, and surface water features that are germane to the RSA-147/148/149 RFI. It is beyond the scope of this report to summarize all of the surface media/source area investigations completed. However, NASA has integrated the majority of the relevant information into their groundwater unit RI. Sections 2.7.1 and 2.7.2 summarize the groundwater RI and LTM.

### **2.6.1 NASA MSFC Operable Unit 3 Remedial Investigation**

NASA is conducting an RI of the groundwater beneath MSFC, designated OU-3 under CERCLA. This unit includes all groundwater, both shallow and deep, and encompasses all of MSFC but also extends beyond Indian Creek to the west, beyond Huntsville Spring Branch to the south, and from 1,000 to 3,500 feet east of MSFC. As such, OU-3 encompasses significant portions of RSA-148 and RSA-149. The OU-3 boundary is shown on multiple figures in this RFI report for reference.

NASA conducted the OU-3 RI using a phased approach. As an early component of the investigation, DPT methods were used to collect screening-level groundwater samples from approximately 610 locations. Over the years, 373 conventional monitoring wells were installed and sampled, the majority of which targeted shallow overburden or bedrock flow components. NASA geophysically logged 76 of the existing monitoring wells (natural gamma, gamma-gamma density, neutron porosity, induction resistivity, and caliper), with a focus on characterizing the overburden and overburden-bedrock interface. Comprehensive sitewide surface geophysical surveys were conducted using a combination of electromagnetics, resistivity

imaging, microgravity, seismic refraction, and multichannel analysis of surface waves. The surveys complemented the reflection seismic completed by the Army (Section 2.3).

Based on the results of these surveys, NASA undertook a deep bedrock characterization program that involved drilling of 14 deep boreholes that penetrated the Chattanooga Shale. Each hole was packer tested in 50-foot increments as the hole was advanced, and upon reaching total depth, the hole was geophysically logged using open hole logs (natural gamma, caliper, fluid resistivity and temperature, and optical televiewer surveys), and tested using hydrophysical methods. The boreholes were then completed as multizone Flexible Liner Underground Technologies, Ltd. Co. (FLUTE) wells with up to six discrete intervals per hole to target the observed water-bearing features/intervals and provide vertical profiling of groundwater quality and head. Borehole characterization data for the NASA deep wells are provided in Appendix C. Available well construction and water level data are included in Appendices B-1 and D, respectively.

As part of the RI, NASA also repeatedly sampled 15 of the perennial springs identified via the Army thermal infrared surveys as well as Army wells installed within and adjacent to the MSFC boundary. Dye tracing was also performed as discussed in Section 2.3 and summarized in Table 2-1.

NASA has also performed considerable vapor monitoring throughout MSFC, including sub-slab soil vapor sampling and indoor/outdoor air sampling. Some of the data were acquired within MSFC-034, for which the Army maintains responsibility.

NASA submitted a draft-final OU-3 RI report in February 2012 which integrated all of the investigative work discussed above as well as Army data available at that time (CH2M Hill, 2012a). As described in Chapter 1.0, through the MOA between NASA and the Army, NASA is responsible for all groundwater (delineation and remediation) within the footprint of MSFC (with the exception of MSFC-034, for which the Army is responsible). The report identified five major plume areas within MSFC (Table 1-2) with contamination in residuum groundwater beneath MSFC, with the most significant and common contaminant being TCE. The RI results indicated that the five plume areas are the result of 15 primary source areas where contaminants were formerly released to the environment. Pertinent information acquired by NASA as part of the OU-3 RI has been integrated into this RFI. Further details regarding the scope of work performed and the results obtained are available in the OU-3 report. More recently, NASA prepared a draft OU-3 focused RI/focused feasibility study report (CH2M Hill, 2017) which focuses on the source areas identified in the 2012 report.

### **2.6.2 MSFC Groundwater Monitoring Program**

Since 1998, NASA MSFC has been conducting periodic monitoring of major groundwater plumes within MSFC and the major points of downgradient groundwater discharges (springs) that have been identified through ongoing site investigations. Sampling is conducted semiannually in March (wet season) and October (dry season). The monitoring network includes 27 monitoring wells, 16 springs, and 4 surface water locations. At the time of preparation of this RFI report, only data through 2013 were available. The available analytical data are included in the nature and extent mapping presented in Chapter 5.0.

### **2.7 Army Surface Media Site Investigations**

The RSA-147/148/149 groundwater units encompass 82 surface media sites. Investigations performed at the surface media sites within RSA-147/148/149 under CERCLA and/or RCRA date back to 1987 and collectively provide data for interpreting the hydrogeology of the groundwater units and delineating the nature and extent of contaminants in groundwater.

Investigation of the surface media sites over time involved soil sampling, monitoring well and piezometer installation, groundwater sampling, water level measurements, and spring and surface water sampling. A total of 751 monitoring wells have been installed by the Army within the three groundwater units as part of surface media site investigations. All of these wells have been sampled at least twice, ranging up to 34 times (F10-RS170). Additionally, 328 screening-level (hydropunch, temporary well, or piezometer) groundwater samples were collected. All available data from Army surface media site investigations through May 25, 2017 have been integrated and utilized in completing this RFI.

Analytical data are included within the digital file provided in Appendix F-1. Monitoring well construction information is included in Appendix B-1. All field documentation for Army wells (boring logs, well construction and development records, sampling records) conducted as part of these surface site investigations are included in Attachment 2.

### **2.8 RSA-147/148/149 RFI Field Investigations**

The RSA-147/148/149 RFI was completed in five separate phases from 2011 to 2017. The details of each effort are described in Sections 2.8.1 through 2.8.5.

#### **2.8.1 RSA-147/148/149 Phase I RCRA Facility Investigation**

The RSA-147/148/149 RFI Phase I fieldwork was performed in accordance with the scope and procedures presented in the site-specific field sampling plan (SFSP) for the RSA-147/148/149 RFI (Shaw, 2011). Field activities for the Phase I RFI were performed from August 2011 to December 2012. The scope of work included the following:



- Six vapor points (147-VP001, 148-VP001, 148-VP002, 148-VP003, 148-VP004, and 149-VP001) were installed and air and groundwater samples were collected in order to document the potential transport of vapors from underlying groundwater where elevated VOCs were observed. Three of the six vapor sampling locations are located within MSFC. Air and groundwater samples were analyzed for VOCs.
- Three deep boreholes were drilled to document the vertical extent of contamination in the vicinity of the RSA-117 site. Two of three planned deep boreholes (147-RS1966 and 147-RS1967) were drilled to depths sufficient to penetrate the Chattanooga Shale (depths ranging from 266 to 288 feet bgs). A surface casing was installed at the third location (147-RS1968), but the hole was not extended to the planned total depth, with further drilling deferred to a later phase. The two open boreholes were geophysically logged (including gamma ray, caliper, fluid resistivity and temperature, optical televiewer logs, and hydrophysical testing). Packer sampling was also planned but not completed due to the presence of dense nonaqueous-phase liquid (DNAPL). FLUTE reactive ribbon liner surveys were performed in 147-RS1966 and 147-RS1967 to a depth of 150 feet.
- Although intended to be 3-port multizone wells, the detection of DNAPL precluded use of such monitoring systems. Nested stainless-steel monitoring wells were designed instead.
- During backfilling of the hole with grout, the lower screening interval of 147-RS1967 was inadvertently grouted over and the well was completed with a single stainless-steel shallow bedrock screening interval.
- Based on the logging and hydrophysical testing results, 147-RS1966 was designed to be completed as a conventional well with a single screening interval. However, the borehole was inadvertently grouted to a depth above the desired screening interval. The borehole was subsequently plugged to the surface and abandoned.
- Well 147-RS1968 was not completed because drillers were having material blowout problems with nearby existing monitoring well Z-RS1232. Well 147-RS1968 was later completed as a conventional well with a single screening interval in July 2014.
- A round of groundwater level measurements was collected in January 2012.
- In addition to the deep drilling described above, 17 overburden monitoring wells were installed at key locations within the RSA-147 and RSA-148 groundwater units in order to delineate contamination indicated based on previous results or to characterize groundwater at sites not previously investigated (such as RSA-249). The samples from the newly installed wells were analyzed for a variety of analytes depending on the location and site or sampling history, including target compound list (TCL) VOCs, TCL SVOCs with low-level polynuclear aromatic hydrocarbon (PAH), TCL pesticides, polychlorinated biphenyls (PCB), TAL metals, and explosives.
- Four springs were sampled in January and February 2012 as part of this field effort. Groundwater samples were collected from within the throat of each spring. Additional collocated surface water and sediment samples were collected at each

spring, and additional downgradient surface water and/or sediment samples were collected for select locations. Samples were analyzed for a variety of analyses including TCL VOCs, TCL pesticides, PCBs, and perchlorate.

### **2.8.2 RSA-147/148/149 Phase 2 RCRA Facility Investigation**

The RSA-147/148/149 Phase 2 RFI fieldwork was performed in accordance with the scope and procedures presented in the SFSP for the RSA-145, RSA-146, RSA-147, RSA-148, RSA-149, RSA-150, RSA-151, RSA-152, RSA-153, RSA-154, RSA-155, RSA-156, and RSA-157 RFI (Shaw, 2012). The Phase 2 RFI performed in November and December 2012 and January 2013 was limited to resampling of select existing wells.

A total of 268 existing wells were sampled as part of the Phase 2 RFI. Samples were analyzed for a variety of suites of analyses based on prior detections and the CSM for the area investigated. The suites included TCL VOCs, TCL SVOCs with low-level PAHs, pesticides, TAL metals, explosives, *Dehalococcoides* sp. (DHC), monitored natural attenuation parameters, and field parameters. The work plan contains the rationale behind each sample location and sample analytical suite selected.

### **2.8.3 RSA-147/148/149 Supplemental Phase 2 RCRA Facility Investigation**

The RSA-147/148/149 supplemental Phase 2 RFI fieldwork was performed in accordance with the rationale and procedures presented in the SFSP for the RSA-147/148/149 RFI (Shaw, 2013a). Field activities for the supplemental Phase 2 RFI were performed from May to July 2013.

As part of this effort, groundwater samples were collected from 51 existing well locations in order to confirm previous results or supplement and complete the analytical suite of previous sampling events. As a result, samples were analyzed for a variety of analyses including TCL VOCs, TCL SVOCs with low-level PAHs, TCL pesticides, PCBs, explosives, TAL metals, perchlorate, and monitored natural attenuation parameters depending on the location and previous sampling history.

Twenty spring locations were also sampled in May and June 2013. Groundwater samples were collected from within the throat of each spring. Additional collocated surface water and sediment samples were collected at each spring, and additional downgradient surface water and/or sediment samples were collected for select locations. Samples were analyzed for TCL VOCs, TCL SVOCs with low-level PAHs, TCL pesticides, PCBs, explosives, TAL metals. Samples from select locations were also analyzed for thianes, thiodiglycol, and perchlorate.

#### **2.8.4 RSA-147/148/149 Supplemental Phase 2b RCRA Facility Investigation**

The RSA-147/148/149 RFI supplemental Phase 2b fieldwork was performed in accordance with the procedures presented in the SFSP for the RSA-147/148/149 RFI (Shaw, 2013a). Field activities for the supplemental Phase 2b RFI were performed from January 2014 to October 2014. The scope of work included the following:

**RSA-147:** The investigations conducted in RSA-147 focused on RSA-117 and RSA-054/055.

- A total of 44 temporary piezometers (147-PZ01 through 147-PZ44) were installed via DPT at the RSA-117 site in order to document the nature and role of perched water and to delineate hot spots indicative of sourcing to groundwater. Of the 44 piezometers, 19 were completed in shallow overburden water-bearing intervals while the remaining 25 were completed deeper within the water table in the overburden. All 44 piezometers were sampled between January 24 and February 5, 2014 and analyzed for VOCs.
- A single overburden monitoring well (147-RS2247) was installed along the northern periphery of the RSA-117 site to serve as an upgradient well. Samples from this well were analyzed for VOCs, pesticides, PCBs, and TAL metals, which are the relevant COCs associated with the RSA-117 site.
- Six deep boreholes were drilled to depths sufficient to penetrate the Chattanooga Shale at RSA-117. Borehole depths ranged from 266 to 311 feet bgs. The open boreholes were geophysically logged, including gamma ray, caliper, fluid resistivity and temperature, and optical televiewer logs. FLUTE reactive ribbon liner surveys were performed in all six open boreholes to document the presence and form of DNAPL entering the holes. Straddle packer testing was performed on up to nine intervals per borehole based on the geophysical logging results. Although straddle packer testing was conducted, no packer sampling was performed given the elevated levels of groundwater contamination observed and the need to complete the wells in a timely fashion to minimize the potential for cross contamination.
- Nested stainless-steel monitoring wells were completed in five of the six deep boreholes (147-RS2248 through 147-RS2251 and 147-RS2540). The completion depths at each borehole were selected based on the logging and packer testing results. A single stainless-steel monitoring well (147-RS1968) was completed at the remaining borehole since this location is paired with an existing well completed in shallow bedrock.
- Hydrophysical testing was completed in only one well (147-RS2248) due to investigation-derived waste issues. However, several of the new wells were paired with Phase 1 RFI boreholes in which hydrophysical testing was performed to the equivalent total depths, notably 147-RS2249 (147-RS1967) and 147-RS2251 (147-RS1966). These data are integrated on the composite logs presented in Appendix B-2.
- Nine wells (147-RS2503 through 147-RS2510 and 147-RS2517) around the RSA-054 capped landfill were drilled, installed, and developed. This included five shallow

overburden, one deeper overburden, and three interface monitoring wells. These wells were intended to replace wells closed as part of the remedial action at that site.

- Thirty-six (21 new and 15 existing) monitoring wells were sampled in March, April, September, and October 2014. Samples from existing wells were analyzed for TCL VOCs and TAL metals in order to confirm previous PSV exceedances. Samples from the nine newly installed wells in RSA-054 and 147-RS2247I were analyzed for parameters known to be COCs of interest or known to be a component of the CSM at the site or area of installation. In accordance with the rationale set forward in the work plan, the suite of parameters analyzed included VOCs, pesticides, PCBs, TAL metals, total dissolved solids (TDS), total organic carbon (TOC), chloride, nitrate, sulfate, dissolved gases, alkalinity, dissolved iron (ferrous/ferric), and DHC. The remaining new wells (147-RS1968, 147-RS2248S, 147-RS2248D, 147-RS2249S, 147-RS2249D, 147-RS2250S, 147-RS2250D, 147-RS2251S, 147-RS2251D, 147-RS2540S, and 147-RS2540D) were sampled in September 2014 with passive polyethylene diffusion bag samplers for TCL VOCs only. The passive sampling method was employed due to the extremely low yield of the deep bedrock wells. Four of the new monitoring wells (147-RS2248S, 147-RS2249S, 147-RS2250S, and 147-RS2251S) were sampled in October 2014 with disposable bailers and analyzed for TCL VOCs, TCL pesticides, PCBs, TAL metals, TDS, TOC, chloride, nitrate, sulfate, dissolved gases, DHC, alkalinity, and dissolved iron (ferrous/ferric). Disposable bailers were used due to the likely potential for encountering DNAPL.

**RSA-148:** The investigations completed in this groundwater unit focused on completing the nature and extent delineation at RSA-061 and RSA-183.

- One deep bedrock multizone/FLUTE (4-port) well (148-RS1978) was installed within RSA-061 in order to delineate the vertical extent of contamination at that site and groundwater flowing south from MSFC. Installation included open hole characterization (including gamma ray, caliper, fluid resistivity and temperature, optical televiewer logs, and hydrophysical testing), discrete groundwater sampling with packers, and select geophysical logging.
- One bedrock well (148-RS2254) and six interface wells (148-RS2511 through 148-RS2516) were installed within or near RSA-183. Bedrock well 148-RS2254 was geophysically logged, including gamma ray, caliper, fluid resistivity and temperature, and optical televiewer logs.
- Existing bedrock borehole Z-RS1237 was completed as a long open borehole. As part of this investigation, the well was to be recompleted from a long open borehole to a nested well with two completion intervals targeting previously identified flow zones/features. However, only one screening interval, 70.5 to 80.5 feet bgs, was completed because the open borehole diameter was not large enough to accommodate a nested well. The well was completed as a conventional polyvinyl chloride monitoring well.

- Eleven of 27 planned springs were sampled as part of this phase of investigation. The remaining springs were not sampled because they could not be located or did not have sufficient flow to be sampled. Sampling was conducted in March 2014. Spring groundwater samples were analyzed for TCL VOCs, TCL SVOCs with low-level PAHs, TCL pesticides, PCBs, explosives, TAL metals, and perchlorate. Surface water and sediment samples were analyzed for a variety of analyses including TCL VOCs, TCL SVOCs with low-level PAHs, TCL pesticides, PCBs, explosives, TAL metals (total and dissolved), perchlorate, TOC, total suspended solids, TDS, and hardness.
- The newly installed wells were sampled in March and July 2014 for TCL VOCs, TCL SVOCs with low-level PAHs, TCL pesticides, PCBs, explosives, TAL metals, TDS, chloride, nitrate, sulfate, thianes, thiodiglycol, and alkalinity. Samples from existing wells were analyzed for VOCs, TAL metals, TDS, chloride, nitrate, sulfate, and alkalinity.

#### **RSA-149:**

- Three shallow bedrock wells (149-RS2255, 149-RS2257, and 149-RS2258) and two overburden wells (149-RS2256 and 149-RS2259) were installed in the MSFC-034 and MSFC-027 areas.
- The newly installed wells were sampled in March and August 2014 and samples were analyzed for TCL VOCs, TAL metals, TOC, nitrate, sulfate, dissolved gases, DHC, thianes, thiodiglycol, alkalinity, and dissolved iron (ferrous and ferric).

A synoptic water level sweep within RSA-147/148/149 was completed on September 29 through October 2, 2014. Water levels were measured in 784 of the piezometers and monitoring wells existing at that time within the three groundwater units. Measurements were planned in another 174 wells but the wells were either dry, lost (could not be located), closed, or inaccessible. The measurements were used to develop the dry season potentiometric map presented in Chapter 3.0.

#### **2.8.5 RSA-147/148/149 Supplemental Phase 2c RCRA Facility Investigation**

Additional fieldwork was conducted in the 2016-2017 time frame in accordance with the field sampling plan memorandum (CB&I Federal Services LLC [CB&I], 2016). Field activities for the supplemental Phase 2c RFI were performed from October 2016 to February 2017. The investigations were intended to address ADEM comments on the Rev 0 RFI report (September 2015), specifically focusing on sites and plumes for which the groundwater units hold the responsibility for groundwater. The scope of work is described in this section.

Five new monitoring wells were installed within the RSA-147 groundwater unit to address comments on the Rev 0 RFI report. The installed wells consisted of four overburden wells (147-RS2845 through 147-RS2848) and one shallow bedrock well (147-RS2844). Three of the overburden wells and the bedrock well were installed to complete the delineation in the vicinity

of RSA-226, RSA-252, and RSA-238. The bedrock well is paired with an existing overburden well at RSA-226 to document the vertical extent of contamination observed in the existing paired overburden well. The wells were sampled in January 2017 and analyzed for VOCs and pesticides, the relevant COCs in this area. The fifth well (147-RS2848) was installed to the north of RSA-139 principally to document the mapped hydraulic gradient and complete the delineation of 2,6-dinitrotoluene (DNT), in response to ADEM comment. This well was sampled in January 2017 and analyzed for 2,6-DNT only.

Fifty-two monitoring intervals at 39 existing locations (many of which were multizone wells) were identified for resampling to address ADEM comments on the Rev 0 RFI. The purpose of the resampling was to confirm specific compounds or classes of compounds which showed a PSV exceedance in the most recent sampling events and/or provide a second sampling event for previously installed wells in the supplemental Phase 2b investigation. As a result, the analytical suite was tailored to target only those COCs of interest at each location (whether VOC, pesticide, explosive or SVOC/PAH); the analytical suite for each well is documented in the work plan. Of the wells identified for resampling, two were dry and could not be sampled. A third well was inaccessible for sampling.

A synoptic water level sweep was conducted over a 3-day period in February 2017 in order to develop a definitive potentiometric surface map of the water table under wet season conditions. The effort focused on those areas within RSA-147 and RSA-148 where the groundwater unit has responsibility for groundwater. Further, wells were scrutinized to focus only on those wells which are representative of the water table (shallow perched wells were excluded). Bedrock wells were only measured where paired with a shallow water table well. Measurements were made in 354 wells and the data used to develop the wet season potentiometric map shown in Chapter 3.0.

## **2.9 Summary of Available Data**

Characterization of the RSA-147/148/149 groundwater units began in 1978. Since that time, a number of studies and investigations (both RCRA and CERCLA) conducted by both the Army and NASA have contributed to the wealth of information available to describe the hydrogeology, nature and extent, and transport of contaminants in groundwater.

- As a result of the characterization activities completed within RSA-147/148/149, the three groundwater units have been well characterized, and all relevant data have been integrated into this RFI.

- Multiple dye traces completed by the Army and NASA serve to describe groundwater flow velocities and vectors from source areas to downgradient wells and springs. Dye traces are summarized in Table 2-1 and results are presented in Chapter 3.0.
- Seismic surveys provide understanding of the geologic structures (chiefly faulting) that influence the formation of karst features and groundwater flow. Seismic survey lines are shown on Figure 2-2.
- Thermal infrared surveys document discrete points of groundwater discharge. Springs have been monitored as part of dye tracing by both the Army and NASA and have been sampled multiple times. A total of 59 springs have been sampled, with 584 samples available for consideration in this RFI. Spring sampling locations are shown on Figure 2-3.
- A total of 1,277 monitoring wells have been installed within RSA-147/148/149 by the Army or NASA. Well locations are collectively shown on Figure 2-4. These data contribute to the understanding of the hydrogeology of the site and provide points for measurement of hydraulic head used in developing potentiometric maps describing groundwater flow. Additionally, the wells have been sampled multiple times (up to 34 times), providing for an understanding of groundwater quality over time (trends, plume stability, etc.). Considering both Army and NASA sources, a total of 8,678 groundwater samples have been collected and are available for use in this RFI.
- A total of 1,241 screening-level groundwater samples have been collected from 1,069 piezometer, open-borehole, or other non-monitoring well locations by the Army and NASA collectively. These data have been used to guide the locations for formal monitoring well installations and bound the extent of shallow groundwater contamination in the overburden. The locations are shown on Figure 2-5.
- Surface water has been sampled by both the Army and NASA, with 632 samples collected from 403 locations across the three groundwater units. Surface water sampling locations are shown collectively on Figure 2-6. Surface water samples were collected at spring sampling locations, with additional downstream surface water samples collected at select springs.
- Soil vapor samples were collected by both the Army and NASA, with a total of 50 samples collected (the bulk of which are located within MSFC). The soil vapor sampling locations are shown on Figure 2-7.

### **3.0 Environmental Setting and Hydrogeology**

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Characterization of groundwater within the subject groundwater units began with the first monitoring well installations in 1978 (RSA-147 and RSA-148) and 1988 (RSA-149). This chapter describes the environmental setting and hydrogeology based on the cumulative investigations described in Chapter 2.0.

#### **3.1 Physical Setting and Climate**

RSA is underlain by three extensive north-south-oriented groundwater watersheds that originate well upgradient of RSA but terminate at the Tennessee River (Figure 1-1). Local groundwater flow divides exist within the 3 watersheds, allowing the groundwater to be divided further into 13 discrete units, which are referred to as RSA-145 through RSA-157. RSA-147 (1,316 acres), RSA-148 (3,561 acres), and RSA-149 (3,915 acres) comprise a total of 8,792 acres in the central portion of RSA (Figure 3-1). The study area is bordered to the west and north by groundwater unit RSA-150, to the north and east by groundwater unit RSA-145, and to the south by groundwater units RSA-146 and RSA-154.

Topographic relief in the study area ranges from an elevation of approximately 550 feet above mean sea level (amsl) at the convergence of Indian Creek and Huntsville Spring Branch to over 1,200 feet amsl at the top of Madkin Mountain along the northeast boundary of RSA-148. However, other than near Madkin Mountain, topographic relief is relatively low, and the majority of the area pertinent to this RFI lies at elevations below 620 feet amsl. Most of the developed areas lie at elevations ranging from approximately 580 to 600 feet amsl. Forty percent (3,538 acres) of the study area lies within the 100-year floodplain, generally defined by the 565-foot elevation contour. Approximately 2,400 acres are registered wetlands, which comprise 27 percent of the study area. The extent of the 100-year floodplain and wetlands are shown on Figure 3-1.

Climate is a primary component of the hydrologic cycle and plays a key role in the hydrogeology of the RSA-147/148/149 groundwater units. Precipitation and evapotranspiration are the two most important factors with respect to site hydrology.

Groundwater recharge occurs from direct infiltration of rainfall and from surface water bodies. Average annual rainfall at RSA is 52 inches and occurs throughout the year, averaging 4.35 inches each month. Peak monthly rainfall typically occurs in February and March, accompanied by rainfall events that are typically of greater duration and intensity than at other times of the year. Historically, the lowest monthly rainfall occurs in August.



Evapotranspiration (evaporation and transpiration) are directly related to seasonal precipitation, temperature, winds, and the growing season. The net amount of water available as either surface runoff or recharge to groundwater is a balance between incident precipitation and evapotranspiration.

On an annual basis, between 75 and 90 percent of rainfall is lost to evapotranspiration (Shaw, 2003a). Groundwater recharge from rainfall is most significant during the winter months after leaf fall and prior to leaf out, when evapotranspiration is minimal. With the onset of the growing season in April, temperatures also increase dramatically, and most, if not all, precipitation is lost through evapotranspiration. Throughout the summer, evapotranspiration exceeds the monthly rainfall, resulting in a water deficit. In contrast, during the winter months, evapotranspiration is minimal, and surplus precipitation is available for groundwater recharge. Discounting runoff to surface water, this leaves approximately 5 to 13 inches of rainfall available to recharge groundwater annually.

Recharge via infiltration is further impacted by impervious cover (paved roads and parking areas and buildings) and drainage infrastructure (such as storm drains and drainage ditches) which serve to rapidly conduct rainfall away. Within the three groundwater units, impervious cover accounts for 8.4 percent of the total area. Impervious area by unit is as follows:

RSA-147	15.38 percent
RSA-148	5.95 percent
RSA-149	<u>8.38 percent</u>
	8.4 percent overall

Further, in developed areas such as exist within RSA-147/148/149, there is a network of above-ground steam lines and underground fire and potable water lines which provide imported water in addition to rainfall recharge. The steam lines have pressure blowdown sumps at intervals along the lines which serve as perennial, localized sources of recharge. In the vicinity of RSA-122, there are several such points where the ground is saturated from the steam condensate. The water supply lines are now over 60 years old, and leaks that provide further points of focused recharge and localized mounding in the underlying water table have occurred and may still be occurring.

### **3.2 Surface Water Hydrology**

Surface water and groundwater are dynamically interconnected within the study area and together play an integral role in the overall hydrogeologic framework of the site. This section provides a description of the key surface water features and surface water hydrology as related to the hydrogeologic setting of the combined groundwater sites.

### **3.2.1 Tennessee River/Wheeler Reservoir**

RSA is bounded to the south by Wheeler Reservoir, which is a run-of-the river impoundment on the Tennessee River. The Tennessee River is the master drain for the entire region and imposes a controlling boundary condition on groundwater flow and surface water discharge. Stage and flow conditions within the river are transient and variable, being the product of reservoir operations at two dams, Guntersville Dam and Wheeler Dam, located 23 miles upstream and 46 miles downstream of RSA, respectively. Prior to construction of these dams in 1936 (Wheeler) and 1939 (Guntersville), the pre-impoundment stage in this reach was approximately 20 feet lower (approximately 537 feet amsl). With the impoundment of Wheeler Reservoir, river stage fluctuates both seasonally and daily in response to reservoir operations as well as in response to rainfall. River stage ranges from 551 feet amsl (low pool) to 556.5 feet amsl (high pool). Low pool stage is maintained during the rainy season from late December to early April as a flood control measure. Beginning in late winter, the reservoir is allowed to fill, and by the end of April, the reservoir has returned to full pool stage. In early to mid-August, TVA begins to draw the reservoir down, creating a transitional, declining stage condition that lasts until low pool stage conditions are once again attained in late December.

Although not directly adjoining the RSA-147/148/149 groundwater unit, both seasonal and storm-related stage conditions in the Tennessee River directly impact stage and flow in Indian Creek and Huntsville Spring Branch, the two principal tributaries which do flow through these groundwater units.

### **3.2.2 Indian Creek**

Indian Creek is a first order tributary of the Tennessee River that originates in a headwater catchment area well upstream of RSA. The creek enters the northwestern part of RSA at an average stage elevation of 605 feet amsl and flows nearly 11 miles in a southerly direction before reaching the Tennessee River. The creek flows south through RSA-149, west of the MSFC boundary. The creek channel consists of dense clay and alluvium. No exposures of bedrock have been observed in the creek bed. In the northern portion of the site, above Martin Road, the creek is up to 20 feet wide and up to 6 feet deep. Below Martin Road, topographic relief diminishes greatly, and the stream is impacted by backwater stage effects of the Tennessee River. Additionally, a number of large-volume springs discharge to Indian Creek in the swampy wetland areas below Martin Road. Stream profiles for lower Indian Creek show the channel to be mostly U-shaped and shallow, with the channel bottom lying at elevations above 548 feet amsl.

Four gaging stations existed along Indian Creek. Only the real-time U.S. Geological Survey (USGS) station where Indian Creek enters RSA (station 03575830) is still operational. Based on the stage gaging data, supported by direct observation, backflow conditions caused by stage

changes in the Tennessee River extend upstream to Martin Road. The backflow conditions are prevalent during high pool stage (April-November) and are only observed in response to storm events in the winter. High pool stage effects are also transmitted back into the wetlands and spring-fed tributaries that connect to Indian Creek as well. Hourly stage was recorded at each of these, but due to backwater effects from the Tennessee River, discharge is only available for the gage at Martin Road and the northern RSA boundary adjacent to Interstate I-565.

### **3.2.3    *Huntsville Spring Branch***

Huntsville Spring Branch originates as discharge from Big Spring in downtown Huntsville and flows in a south-southwesterly direction before joining Indian Creek at mile 4.7 on RSA. The drainage area for Huntsville Spring branch encompasses 46.9 square miles. The stream receives considerable runoff and other discharge from the industrialized and developed parts of southwest Huntsville before entering RSA at mile 9.75 near Martin Road on the east side of RSA. Huntsville Spring Branch and its associated wetlands form the southern portions of the study area.

Where flowing through RSA, the channel ranges up to 80 feet wide and is incised into dense mud and clay. Bedrock outcrops have been observed in the creek bed in the reach between Patton Road and the confluence with McDonald Creek. Stream profiles indicate the stream is shallow, with the deepest point of the channel (elevation 550.8 feet amsl) occurring near the Dodd Road Bridge. Similar to Indian Creek, seasonal (high pool stage) and storm-related stage changes in the Tennessee result in backflow conditions that extend from the confluence with Indian Creek up to the Patton Road bridge. The high pool stage conditions also project outward into the surrounding wetlands.

There were three continuous-recording surface water gauging stations along Huntsville Spring Branch on RSA. A fourth gage, operated by the USGS as a real-time monitoring station, is located upstream of RSA at Johnson Road Bridge. Due to the backflow on the lower reaches of the creek, discharge is only measurable at the upstream Martin Road and Johnson Road stations. Stream flow discharge in Huntsville Spring Branch at Martin Road ranges up to 4,593 cubic feet per second (cfs), with a median flow of 50.4 cfs.

The course of Huntsville Spring Branch between miles 2.4 and 4.85 has been diverted as part of the Olin DDT abatement completed in the 1980s. Previously, Huntsville Spring Branch followed a northward meander loop along the north side of the DDT abatement dike and road (Shaw, 2003a), following a course along the toe of slope below RSA-010 and RSA-053.

### **3.2.4 Interior Streams, Drainages, and Ponds**

Within RSA-147/148/149, a network of engineered drainage ditches conveys runoff to unnamed ephemeral streams and the surrounding wetlands. Only four perennial surface water features drain the upland areas of RSA-147/148/149 exclusive of MSFC. The first is a small stream within RSA-147 that originates just north of the RSA-122 site with significant groundwater contribution from a small spring-fed (RSP-1504, RSP-1506, and RSP-1510) wetland to the southeast of RSA-122. This stream then flows to the south along a course parallel to Patton Road before discharging into Huntsville Spring Branch, just downstream of the Patton Road bridge. Bedrock is exposed in the stream bed all along its course along Patton Road. Shaw established and rated a gage on this feature upstream of the impacts of Huntsville Spring Branch (P3 on Figure 2-1). Stream discharge was estimated to range from 0.2 to 8.2 cfs, with a median discharge rate of approximately 1.0 cfs (Shaw, 2004d).

The second perennial surface water feature is the man-made DDT drainage ditch which flows from the RSA-117 area of RSA-147 to drain into the wetlands below RSA-060. The third is an ephemeral stream that originates from seepage within the deep ravine that separates RSA-010 and RSA-053 within RSA-148. This feature also drains to the DDT Abatement area wetland north of Huntsville Spring Branch. Stream flow discharge rates are not available for these features.

A large wetland area (referred to as the Motherlode Swamp in NASA MSFC documents) lies at the toe of slope below RSA-010, RSA-053, and RSA-060, in part due to the Olin DDT abatement effort. As part of the abatement, Olin installed a sheet pile wall to contain contaminated sediment and isolate it from Huntsville Spring Branch, which was diverted as part of that same effort. The area above (north) of the sheet pile wall is drained through a narrow constructed channel which ultimately discharges to Huntsville Spring Branch just upstream of the Dodd Road bridge. The Army established a stream gaging station at the downstream end of this channel (station P-4 on Figure 2-1) and monitored flow from 2000 to 2002. Observed flow ranged from 0.11 to 21.97 cfs, with a median discharge rate of 6.31 cfs (Shaw, 2004d). Although this portion of the wetland receives input from the aforementioned ephemeral stream, the DDT drainage ditch, and diffuse runoff from the upslope areas, a large number of springs are evident on the thermal infrared imagery, which suggest considerable groundwater contribution to the discharge rates observed at station P4 as well.

Finally, a perennial stream channel extends from spring RSP-0694 (also known as NASA Spring) to Indian Creek upstream of Martin Road. Low-flow measurements performed in the 1970s by the USGS documented RSP-0694 discharge rates of between 3.5 and 10.5 cfs, with peak discharge in excess of 20 cfs.

### **3.2.5 Wetlands**

Wetlands occupy 27 percent of the surface area of the study area and are generally considered to represent an expression of the water table at the ground surface. The wetlands are also sustained by discrete points of groundwater discharge from dozens of seeps and springs. Seasonal and storm-related stage changes in the Tennessee River, Indian Creek, and Huntsville Spring Branch impact the stage within the wetlands as well, including those impounded above the DDT containment structures. During the high pool stage/dry conditions described previously, the wetlands become flooded and inundate the springs normally exposed and flowing during the low pool stage/wet season. This creates an opposing head to groundwater discharge and a decreased gradient that projects back into the aquifer.

### **3.3 Geology**

The bedrock stratigraphy and structure are the two components of the site geology that influence groundwater occurrence and flow within RSA-147/148/149. Sections 3.3.1 through 3.3.3.3 describe the geology of the study area, principally derived from borehole drilling and reflection seismic profiling within the RSA-147/148/149 groundwater units.

#### **3.3.1 Stratigraphy**

##### **3.3.1.1 Overburden**

Bedrock is exposed at the surface in only a few locations within RSA-147/148/149 and typically covered with a mantle of unconsolidated overburden that ranges from 1 to 115 feet in thickness, with the maximum depth to bedrock observed at well MC-MW-051D, near Indian Creek in the western portion of MSFC. The top of bedrock surface shown on Figure 3-2 is defined by 1,560 penetrations, including monitoring well, soil, DPT piezometer, and geotechnical engineering borings which encountered or penetrated into bedrock. The depth of bedrock is variable and may vary locally as much as 60 feet between adjacent boreholes, particularly in the southern portion of RSA-147/148/149 where the upper Tusculumbia Limestone is still present.

In developed areas, much of the surface has been reworked and graded such that man-made fill of varying thickness may be first encountered in the subsurface. Otherwise, the unconsolidated overburden overlying bedrock consists of a fat, silty clay with varying amounts of residual chert, which may occur as isolated fragments, to layers of chert gravel encased within clay. This residuum was developed from in situ weathering of the parent bedrock and therefore reflects the lithology of the rock, being more chert rich where underlain by the lower Tusculumbia Limestone or upper Fort Payne Formations described below. Approaching the top of bedrock and where saturated by groundwater, the residuum is more weathered, with much of the finer silt and clay removed and a higher percentage of chert gravel remaining. This constitutes the “rubble zone”

discussed in NASA MSFC documents. Given the relief on the top of bedrock and dipping bedrock (with corresponding relict dip within the residuum), these intervals, although commonly encountered, are laterally discontinuous.

### **3.3.1.2 Bedrock**

Bedrock formations underlying RSA-147/148/149 and pertinent to this RFI include the Mississippian-age Tuscumbia Limestone and Fort Payne Formation; the Mississippian/Devonian-age Chattanooga Shale; and the underlying, undifferentiated Silurian or Ordovician-age rock. Stratigraphically younger geologic units, including the Hartselle Sandstone and Monteagle Limestone, are found in the higher elevation slopes of Madkin Mountain to the north, but are not relevant to this RFI and not discussed further.

A series of cross sections have been developed (Figures 3-3 and 3-4) which depict the stratigraphy and structural geology underlying RSA-147/148/149. The section locations are shown on the inset maps on each figure. These sections were developed based on borehole data but also integrate key information from maps presented in this chapter. Fault locations and vertical offsets along faults are also shown. Individual fault blocks are informally labeled to aid discussions.

As can be seen from the sections, regional and local formation dip along with structural features dictate the uppermost bedrock geologic unit encountered below the overburden. Erosion and subsequent weathering of the generally southerly dipping, stacked bedrock layers result in progressively older bedrock being exposed in subcrop moving from south to north across RSA-147/148/149.

Within the RSA-147/148/149 groundwater units, 262 boreholes have been drilled into bedrock for monitoring well installation, ranging in depth up to 310 feet and spanning the stratigraphic units pertinent to this report. Twenty-nine of these boreholes encountered the top of the Chattanooga Shale, a regional stratigraphic marker, extending up to 31 feet into the underlying undifferentiated Silurian or Ordovician bedrock. Twenty-seven deep borings were geophysically logged, including optical (and/or acoustic) televiewer, of which 24 were subjected to hydrophysical testing and packer testing. Borehole logging data are provided in Appendix C, while composite plots of deep bedrock wells drilled by the Army are provided in Appendix B-2. The bedrock stratigraphy discussed below is based on the bedrock boreholes drilled and characterized within RSA-147/148/149, supplemented by information gained from investigations across RSA. Formation tops (depth and elevation) for the Chattanooga Shale and the Fort Payne Formation are provided for all wells within the study area in Appendix B-1.

The Tuscumbia Limestone is the uppermost bedrock unit first encountered in subcrop below the overburden throughout much of the study area. As can be observed from the cross sections (Figures 3-3 and 3-4), the Tuscumbia Limestone thickness varies as a result of erosion and weathering as well as variable depth to bedrock and faulting. While a complete Tuscumbia Limestone section is commonly encountered south of Huntsville Spring Branch, north of this stream within RSA-147/148/149, the uppermost Tuscumbia has been progressively removed through erosion and subsequent weathering such that the overall formation thickness decreases in a northerly direction. The occurrence and thickness of the Tuscumbia is also impacted by faulting. In general, the Tuscumbia is thicker in down-dropped fault blocks. As a result, progressively older strata of the Tuscumbia are exposed in subcrop moving to the north, with the Tuscumbia absent in select areas in the northern part of RSA-147/148/149, where the Fort Payne is the uppermost bedrock formation encountered. Areas where the Tuscumbia are absent include the vicinity of well MC-MW-051D near Indian Creek (Figure 2-5), the western portion of MSFC, the north-central portion of RSA-148 near surface media site RSA-049, and the central portion of RSA-147 near surface media site RSA-056. The maximum observed thickness of the Tuscumbia Limestone is 147.6 feet at well MC-MW-091 in the center of the study area, north of surface media site RSA-141.

The Tuscumbia Limestone consists of thick to massively bedded, “clean” micritic limestone in the uppermost 120 to 140 feet of the formation, but the basal 60 or so feet (informally considered the lower Tuscumbia through RSA) becomes increasingly thinner bedded and chert rich, transitional to the underlying Fort Payne. These lithologic and stratigraphic differences play a significant role in the karst development within the Tuscumbia and thereby the water-bearing and transmissive nature. High angle fractures generally terminate at bed boundaries, and given the increased bed thickness of the upper Tuscumbia, the fractures are longer and solution features developed along fractures tend to have more vertical height. Due to the relatively pure nature of the upper Tuscumbia Limestone, the rock is more subject to dissolution such that in combination, the karst development within the upper Tuscumbia is much more developed. In the lower 60 feet of the Tuscumbia, as the bedding becomes thinner with increasing chert approaching the Fort Payne contact, solution features become fewer and of smaller dimension both vertically and laterally.

Considering the residual thickness of the Tuscumbia, karst development in the upper bedrock is better developed in the southernmost portions of RSA-147/148/149, where the upper Tuscumbia is still present. Conversely, karst development in the Tuscumbia, where still present, decreases moving towards the north as the upper Tuscumbia has been removed. As mentioned previously, faulting also dictates the residual thickness of the Tuscumbia.

The contact between the Tuscumbia and the Fort Payne is lithologically indistinct, but recognizable on gamma ray logs as a prominent decrease in natural gamma counts. The upper Fort Payne is characterized by intervals of impermeable chert with interbedded limestone or dolomite. Bedding in the Fort Payne Formation is typically nondistinct or not preserved, replaced by abundant stylolites, which are pressure-solution features within the rock. Although the chert lithology is more brittle than the limestone of the upper Tuscumbia, the lack of bedding results in few long through-going fractures. Any fracturing typically terminates at the many stylolites. This, coupled with the relatively insoluble nature of the bulk of the rock, leads to decreased karst development. Within the upper Fort Payne, voids ranging up to several tenths of a foot in height are seen, typically isolated by impermeable chert-carbonate rock both above and below. Neither individual stylolites nor solutionally enlarged stylolites can be correlated for any distance from well to well. The lower Fort Payne is similar to the upper Fort Payne, but with an increase in stylolites and decrease in fracture density. A thin greenish-gray shaley zone is often encountered in the basal Fort Payne just above the Chattanooga Shale.

Due to the lithologic nature of the Fort Payne, this formation is largely insoluble and impermeable. Stylolites may be weathered or slightly solutionally enlarged and serve as primary water-bearing features where developed, but these features are not laterally pervasive (i.e., correlable from well to well). Solution enlargement of stylolites and fracturing are most developed along fault zones, with areas between faults remaining impermeable.

The thickness of the Fort Payne varies slightly but across RSA is typically around 140 feet on average. From fully penetrating boreholes within RSA-147/148/149, the Fort Payne has been documented to range from 143.1 to 160.3 feet thick, with an average of 147.4 feet. Variations from the average thickness likely represent apparent thickness measurements in boreholes encountering more steeply dipping beds (i.e., not true thickness measured perpendicular to the bedding surface). Where the Tuscumbia Limestone has been removed, the Fort Payne is the uppermost bedrock unit encountered below overburden. Progressive weathering or erosion of the Fort Payne results in less than the full thickness in a number of locations. Projecting the average Fort Payne thickness up from the observed top of the Chattanooga Shale, as much as 48 feet of the upper Fort Payne is missing in select locations.

The Mississippian-Devonian age Chattanooga Shale underlies the Fort Payne. The shale ranges in thickness from 1.5 to 19.1 feet within these three groundwater units, with an average thickness of 6.3 feet. The Chattanooga Shale was deposited over an exposed, weathered bedrock topographic surface marking a regional unconformity surface. This accounts for the thickness variability of the Chattanooga Shale, which is thicker over former topographic lows and thinner over topographic highs.



The Chattanooga Shale is a thin-bedded, fissile, black, organic-rich shale. The Chattanooga Shale is readily identified on drilling and televiewer logs and has a distinctively elevated gamma signature on natural gamma logs. As such, the Chattanooga Shale is an excellent stratigraphic marker. Pyrite and gypsum are commonly observed within the shale, precipitated as fracture and vug fill materials. These minerals were also found within the basal Fort Payne units. The observation of pyrite within the Chattanooga Shale serves to document reducing conditions at depth, as indicated by the presence of sulfate and sulfide minerals.

It should be noted that the Chattanooga Shale is a primary source rock for the formation of hydrocarbons. RSA is situated north of the Black Warrior basin, an oil and gas-producing province. Residual hydrocarbons were identified as being present throughout the lower Tusculumbia and Fort Payne section within the study area and were observed in logging elsewhere on RSA. The occurrence of the naturally occurring hydrocarbons is also indicated by the presence of benzene, toluene, ethylbenzene, and xylene in deep groundwater samples. The MSFC prepared an evaluation of these chemicals in groundwater and concluded the occurrence in deep groundwater is the result of naturally occurring petroleum hydrocarbons (CH2M Hill, 2011). Natural gas was produced at one time from the Fort Payne in a well field located within 1 to 2 miles of the northeastern boundary of RSA. Methane gas was encountered below the Chattanooga Shale north of RSA.

### **3.3.2 Bedrock Structure**

The structural framework of the RSA-147/148/149 study area is complex. Reflection seismic surveys completed within the study area and across RSA revealed that the bedrock is extensively faulted. The faults can be correlated across multiple seismic lines and therefore extend for miles, with faults extending through the entire bedrock stratigraphic section, including the Chattanooga Shale and overlying bedrock units. Copies of the seismic survey reports are provided in Appendix A. A number of normal faults and fault splays have been mapped, with an overall north-south trend across RSA-147/148/149 (and RSA in general). A typical seismic profile line with interpreted faults is presented on Figure 3-5. This seismic profile line also shows the Chattanooga Shale, the principal shallow seismic reflector. A structure contour map of the Chattanooga Shale (Figure 3-6) was developed based on the seismic profiles coupled with known Chattanooga Shale elevations where directly encountered or projected from shallower Fort Payne tops in deep boreholes. The faulting results in a series of down-dropped and rotated fault blocks (Figure 3-3). From the seismic profiles and the structure contour map, the dip of the beds within a given fault block differs markedly from the assumed southerly dip or the dip in an adjacent fault block. Vertical offset along faults appears to range from 10 to as much as 140 feet.

Delineation of the structure of the bedrock at the Chattanooga Shale horizon coupled with the observed range of formation thicknesses allows for identification of the specific stratigraphic intervals where subsurface karst features and groundwater flow zones were observed in open boreholes and completed wells. This in turn allows for an improved understanding of the architecture of the aquifer in terms of stratigraphy, degree of karstification, groundwater flow, and geochemistry.

### **3.3.3 Karst Development**

Karst is well developed within the RSA-147/148/149 study area and evident at the surface as sinkholes and in the subsurface as solution cavities and voids. Figure 3-7 presents an inventory of observed surface and subsurface karst features in the study area. As described previously, the development of karst features in the subsurface is closely related to the stratigraphy and lithologic character and the structural features, notably faults and fault-related fracturing that focus groundwater flow and thus karst development.

#### **3.3.3.1 Surface Karst Expression**

Sinkholes observed at the surface are telltale indicators of karst development at depth. Within RSA-147/148/149, a number of sinkholes have been mapped using late-1930s and early-1940s stereographic aerial photographs. Since much of the developed area within the study area has been filled and graded, many of these sinkholes are no longer apparent in the field. There are no known caves within the study area. The nearest cave is Fox Den Cave, which is located on the flanks of Madkin Mountain and developed within the upper Mississippian Monteagle Limestone.

Sinkholes within the RSA-147/148/149 groundwater units shown on Figure 3-7 vary in size from less than 0.1 to 93 acres. In the latter case, a large closed depression extending nearly 2 miles in length in the central part of RSA-148, the sinkhole is formed within and along a narrow down-dropped fault block (graben). As shown on Figure 3-7, many of the sinkholes appear to align with or be bounded by mapped faults, highlighting the significance of faulting in karst development.

Many of the sinkholes identified from the early 1940s and 1950s aerial photographs within RSA-147/148/149 have been graded over as part of construction development. Karst development is an ongoing process, and occasionally, previously formed features are “reactivated” or new sinkholes formed over time. Dropouts or collapses within MSFC have been reported in the vicinity of Buildings 4705, 4707, and 4647, east of Building 4671, and east of Dodd Road (CH2M Hill, 2012a). In the RSA-117 area of RSA-147, for example, a moderate sinkhole was mapped from the predevelopment aerial photographs. The area was later graded, utilities were installed, and a road was paved over the former sinkhole. More recently, a cover

collapse sinkhole formed in the same location, consuming portions of the road. It is suspected that a leaking water line that ran under the road resulted in increased solution and settling over time, which caused the sinkhole.

Similarly, while constructing the new AMC headquarters facility on the north side of Martin Road several years ago, other former sinkholes were rejuvenated. While the buildings were constructed using caissons seated into competent rock, four shallow ponds were also excavated into the residuum and filled with water. A series of small cover collapse sinkholes formed overnight and drained several of the ponds. Several sinkholes had been mapped on the predevelopment aerial photographs in this area. Considerable grouting of the voids was required to complete the construction of the ponds which serve as landscaping features and runoff control basins.

#### **3.3.3.2 Epikarst**

The highly variable bedrock topography underlying the study area is the product of in situ solution weathering of the bedrock surface, forming deeply incised rock crevices, or cutters, and intervening pinnacles. This pinnacle and cutter topography is referred to as the “epikarst.” The epikarst serves to facilitate hydraulic communication between the fractured and karstic bedrock and the saturated overburden. However, where the uppermost bedrock is less permeable, the epikarst is also less developed and there is less communication between the overburden and the bedrock.

#### **3.3.3.3 Nature of Karst Development**

Within RSA in general, large solution cavities have been observed in the subsurface in the upper Tuscumbia Limestone due to its massive thick bedding and “clean” limestone lithology. In contrast, the lower Tuscumbia and Fort Payne Formations consist of thin, interbedded dolomitic limestone, dolomite, and chert. Vertical fractures and high-angle fractures generally terminate at bed boundaries. Therefore, cavity heights are limited in intervals with thin bedding, and solution features tend to be wider than they are tall. The numbers of cavities observed in boreholes are shown on Figure 3-7. Overall, for the reasons discussed above, karst development in the basal 60 feet of the Tuscumbia Limestone and the upper 80 feet of the Fort Payne is lower than that observed in the upper Tuscumbia and typically associated with solution stylolites or fracturing. Solution features decrease further in the lower 60 feet of the Fort Payne, largely due to decreased circulation of water. Exceptions are generally limited to locations along faults.

### **3.4 Groundwater Hydrology**

An understanding of the hydrology of RSA-147/148/148 groundwater units is essential to evaluating the nature and extent of contaminants in groundwater as well as remedial decision

making to abate contamination where warranted. At RSA-147/148/149, this understanding is based on information obtained as follows:

- A total of 1,207 boreholes drilled for monitoring well installation (total of 1,278 monitoring wells/intervals constructed).
- A total of 1,137 DPT/hydropunch piezometers
- Thermal infrared surveys to identify springs and subsequent characterization of those springs
- Flowmeter surveys
- Aquifer testing
- Dye tracing.

A number of wells have been closed (103 as of this this writing). Of the remaining 1,175 existing monitoring wells, 870 are completed in the overburden, 52 are completed as interface wells (with screens straddling the overburden-bedrock interface), and 253 bedrock monitoring wells/intervals were completed in 205 distinct bedrock boreholes. As described previously, 29 boreholes penetrated the Chattanooga Shale, with 24 of these wells having been highly characterized. Maps showing springs and monitoring wells within the study area are presented on Figures 2-3 and 2-5, respectively.

The nature of the flow system at RSA-147/148/149 is a product of the underlying stratigraphy, structural geology, seasonal recharge, and surface water stage conditions. Throughout this report, groundwater is distinguished as shallow and deep, consistent with presentations in other groundwater unit RFI reports, where:

- The shallow groundwater zone which constitutes the unconfined water table includes the overburden and upper bedrock to depths of 120 feet bgs.
- The deep groundwater zone includes groundwater in deeper bedrock at depths greater than 120 feet bgs. Groundwater occurrence at these depths may be locally confined or semiconfined.

The 120-foot depth distinguishing shallow from deep groundwater is somewhat arbitrary but serves to document observed changes in groundwater flow and geochemistry in a broad sense. Given that the strata dip to the south and are removed by erosion moving from south to north coupled with recognition that faulting has resulted in fault blocks with unique dips and depths to various formations, there is no absolute or correct cutoff to apply based on stratigraphy. Further,

from examination of RSA-wide data (specifically other highly characterized groundwater units such as RSA-146), this approach appears defensible.

### **3.4.1 Groundwater Occurrence**

#### **3.4.1.1 Shallow Groundwater**

Groundwater occurs as an unconfined water table aquifer within the overburden and upper bedrock units, with groundwater typically first encountered in the overburden. Although the groundwater within the overburden is under unconfined conditions, groundwater elevation measurements from individual wells are not, in many cases, usable to depict regional or localized groundwater flow conditions for the following reasons:

- The overburden is nonhomogeneous; more clay-rich overburden sediments will transmit water more slowly than overburden sediment containing appreciable amounts of silt, sand, or chert. Therefore, vertical and horizontal groundwater movement, including gravity drainage of the vadose zone, occurs at different rates within the overburden resulting in the presence of localized perched groundwater and residual mounding of groundwater in the overburden. The mounding appears to be more pronounced around buildings or built-up areas perhaps due to localized disturbances that modify near surface infiltration rates of the overburden in those areas.
- Continuous water level monitoring has shown that groundwater levels within individual wells are constantly in flux and change based on river stage and precipitation events. Although all wells appear to respond to changes in river stage or precipitation, the response does not appear to be uniform.
- Additionally, the topography on top of the limestone bedrock surface is complex and the depth to bedrock at any location on RSA is dependent on the presence of buried sinkholes and cutters (i.e., bedrock lows) and pinnacles and floating blocks of bedrock (i.e., bedrock highs) which have formed in response to weathering of the limestone and the joint and/or fracture patterns in the rock. It is very typical for borings offset only tens of feet to have widely different depths to bedrock. Shallow refusal on a pinnacle or bedrock high may result in finding “perched” groundwater on or along the overburden / bedrock interface.

Figure 3-8 presents the potentiometric surface for the shallow unconfined, water table aquifer based on synoptic measurements collected in September and October 2014. This surface is also depicted on the cross sections. Historical water level statistics for each location are provided in Appendix D.

There are overburden wells on RSA that monitor localized groundwater occurrences but do not represent regional hydraulic head and should not be included in the overall RSA-147/148/149 groundwater potentiometric surface map. The February 2017 potentiometric surface map (Figure

3-9) was created using interface wells and overburden wells that encountered the top of bedrock or were drilled several feet (less than 10) into bedrock. The available data suggest these wells are most representative of regional groundwater flow. In addition, wells with groundwater elevations that were higher than the approximate regional surface were also culled from the data used to create the potentiometric surface map with the rationale that these wells were reflecting localized mounding due to bedrock highs or the presence of lower permeability

The Army performed continuous water level monitoring of select wells and springs within RSA-147/148/149 along with surface water stage monitoring (Shaw, 2003a). Figure 3-10 is a composite hydrograph plot for a paired overburden well (H52-RS752), a bedrock well (H52-TS835), a nearby spring (RSP-0824), Huntsville Spring Branch, and the Tennessee River. The monitoring locations are shown on Figure 2-1. Figure 3-10 illustrates that the stage of Huntsville Spring Branch is directly impacted by stage in the Tennessee River, and in turn, directly influences groundwater elevation in the spring and the overburden and shallow bedrock wells. The data document that the vertical gradient in the overburden and bedrock wells (H52-RS752 and H52-RS835, respectively) follows closely the change in stage elevation in the Huntsville Spring Branch. The figure also indicates that in general, the overburden and bedrock are in hydraulic communication. Further, the vertical gradient between the overburden well H-52-RS752 and bedrock well H52-RS835 is neutral in the summer months, when both are impacted by high pool stage, but becomes dominantly upward during the winter and spring during periods of bulk groundwater discharge.

#### **3.4.1.2 Deep Groundwater**

Features controlling groundwater flow are much less numerous and more discrete with increasing depth in bedrock, such that flow in bedrock becomes stratabound within karst features, only to move vertically when faults or other vertical hydraulically conductive features are encountered. Solution-enlarged fractures and stylolites are encased in impermeable chert-rich rock, such that confined or semiconfined flow exists in deep flow features, at least locally. Consequently, groundwater in the deep aquifer component is largely semiconfined to confined.

Groundwater elevations within bedrock may vary widely over time within an individual well. This is illustrated on the summary water level table provided in Appendix D. Water levels in paired wells completed in shallow and deep groundwater zones have been observed to vary more than 25 feet, although the deep zone wells are generally less responsive to short-term recharge events, if at all. This further illustrates the discrete nature of groundwater occurrence in the deep portions of the aquifer.

Water movement through the bedrock is a function of the lithology of the rock (which determines the primary porosity) and any secondary porosity that may be imparted by fracturing or solutional enhancement. The hydraulic conductivity of the bedrock has been measured using conventional slug and pump tests, packer testing, and hydrophysical testing. Figure 3-11 presents a graphical summary of the range of hydraulic conductivity by geologic formation. Since these are stacked layers such that the oldest formations are also the deepest, this plot also reflects changes in hydraulic conductivity as a function of depth. The figure documents that although the range of conductivities for the various formation overlap, there is a trend towards decreasing hydraulic conductivity with depth. This is also consistent with a transition to increasing insoluble chert within the Fort Payne and the nature of the Chattanooga Shale.

Highly transmissive solutional porosity features ranging up to 10 feet were observed in the Tusculum Limestone from borehole and optical televiewer and caliper logs. Additionally, features up to several tenths of a foot in height were observed within the Fort Payne Formation. These features generally occur within otherwise impermeable rock. Although a number of these features have been encountered, the lateral extent of these features is unpredictable and likely to be fault block dependent (i.e., formed within a specific stratigraphic horizon or elevation within one fault block and, possibly, in different intervals within other fault blocks). With increasing depth, confined or semiconfined conditions exist, and such conditions are also likely fault block dependent. Hydrophysical logging data from open boreholes document that the heads within discrete water-bearing features and intervals are unique and create gaining and losing intervals within an open borehole. In a borehole, flow may enter from a feature with higher head and exit the borehole from a feature with a lower head. Where not penetrated by a borehole, these zones would be confined or at least semiconfined and likely not communicate, except along faults. Head measurements in completed multizone or paired/nested wells confirm that distinct flow features and zones have unique and separate head domains, all of which respond differently to hydrologic conditions. While upward or downward gradients suggest the potential for vertical groundwater movement, these intervals are actually semiconfined and independent.

Figure 3-12 is a conceptual model for the RSA-147/148/149 study area that illustrates the following discussion. Faults and vertical fractures facilitate communication between the shallow water table flow component and the deeper stratabound flow zones locally. The faults cut across all beds and facilitate groundwater flow vertically in response to head differences in the vicinity of these features. Within fault blocks, the flow is at least semiconfined. Karst flow networks are likely developed along (or subparallel to) faults. It is expected that solution features extend at least a marginal distance into fault blocks on either side of a fault, but karst networks may also be fault bounded and unique to each fault block. It is expected that groundwater flowpaths are

stair-stepping from transmissive flow zones/features on one side of a fault, along the fault, whether upward or downward, to continue in the next most hydraulically preferable feature on the other side of the fault.

The faults may in part serve as primary pathways themselves, but the continuity of flow along a fault plane cannot be resolved. Faulting is accompanied by enhanced fracturing along the fault plane, which in conjunction focus groundwater flow and act as primary controlling features. The increased flow along these zones enhanced solution of the host carbonate rock such that karst features hosting groundwater flow are most developed parallel to the trace of the faults. Based on televiwer logs of boreholes drilled in the interior portions of fault blocks (i.e., intrablock positions), the rock is considerably less weathered or solutioned, particularly with increasing depth. Karst development within the epikarst zone or connected uppermost bedrock in the intrablock position likely connects to the conduits formed along the faults as the latter are the most efficient drains for transmitting water. Consequently, the karst flow networks in intrablock positions are expected to be less developed, serving as tributary flow components of the greater fault dominated conduit networks. As can be expected, the resultant bedrock flowpaths within the intrablock areas are complex and beyond resolution.

Just as the degree of solution porosity development at depth likely varies among the different fault blocks, the head distribution within each confined interval may be unique within each fault block. However, the faults serve to facilitate communication between the shallow karstic flow component and the deeper confined or semiconfined flow zones. Therefore, the depth of active groundwater circulation is likely deeper along faults, as suggested by site geochemical data.

### **3.4.2 Groundwater Flow and Discharge**

The potentiometric surface maps (Figures 3-8 and 3-9) were developed for the unconfined water table aquifer.

Groundwater flow directions in the shallow water table aquifer follow the mapped gradients from potentiometric highs to lows. Overall, the lowest heads occur within the wetlands flanking Huntsville Spring Branch along the southern boundary of the groundwater units. Therefore, shallow groundwater flow is from north to south, towards Huntsville Spring Branch and Indian Creek. However, the water table is a subdued replica of topography and punctuated with a number of potentiometric highs such that locally, flow directions may vary from the general flow direction. As shown on Figures 3-8 and 3-9, the large sinkhole in the central portion of RSA-148 creates a broad potentiometric low, with convergent flow towards this feature from all sides. Ultimately, this low drains to the wetlands that lie to the south, below RSA-010 and RSA-053. Similarly, on the west side of MSFC, shallow groundwater flow is towards a series of buried



sinkholes that result in a broad water table low that extends to the southeast toward Indian Creek. Additional large-volume dewatering of the NASA Saturn Test Stand (approximately 1.5 million gallons per day [mgpd]) in the southwestern corner of MSFC also contributes to the potentiometric low. Once reaching the wetlands to the south and west, the gradient declines sharply, forming a broad discharge zone.

Mounding associated with point recharge from anthropogenic sources (water lines, steam lines, and roof drains) further results in flowpaths that, at least on a localized scale, may deviate from the overall southerly flow. Such mounding is most pronounced in developed areas within the groundwater units where there are more of these features. However, flowpaths emanating from these localized highs merge into the regional hydraulic gradient with distance from the recharge points.

While flow directions within the shallow water table aquifer are predictable and mappable, the flow in the deeper bedrock is more complicated due to the structural and stratigraphic factors described above. The exact flowpaths groundwater follows in the bedrock are largely beyond resolution due to the complexity of the system. Groundwater within the deeper flow component is largely semiconfined to confined and constrained to the discrete features and pathways developed in rock. Flow within the bedrock follows fractures, faults, and solution conduits formed along the faults/fractures. In general, groundwater in the bedrock flows from the upland, upgradient areas to the south to discharge in the wetland areas that wrap around the downgradient end of the RSA-147/148/149 groundwater units along Huntsville Spring Branch and Indian Creek.

Two sources of information are available to document groundwater flow velocities within the RSA-147/148/149 groundwater units. Both the Army and NASA performed heat pulse flowmeter surveys in select wells in the 1999-2000 time frame (CH2M Hill, 2012a, Shaw, 2004a). Based on these one-time measurements, the velocity in the overburden and shallow bedrock ranged from 0.15 to 8.4 feet per day (ft/day). Comprehensive dye tracing performed at RSA-147/148/149 by the GSA, NASA, and the Army between 1992 and 2002 provides flow vector and velocity information from points of injection to downgradient monitoring points. A total of 22 individual dye traces were performed. The dye trace studies are summarized in Section 2.3 and Table 2-1. Figure 3-13 shows the composite dye trace results from GSA, NASA and Army tracing. Additional, more detailed figures from the 2004 central RSA dye trace report (Shaw, 2004a) for each dye are presented in Appendix B-4.

All of the Army injections were made into bedrock wells to depths ranging up to 150 feet bgs. Tracing by others included injections into shallow bedrock and overburden wells. Hydraulic

connections were demonstrated from points of injection to downgradient points of detection at distances ranging up to 14,949 feet. Flow rates for Army bedrock injections on average ranged from 528 to 1,573 ft/day, with a maximum velocity of 3,258 ft/day. Flow velocities from the NASA tracing from bedrock injections ranged from 4 to 2,520 ft/day, averaging 602 ft/day. Injections made in the overburden but detected in the bedrock (or vice versa) were much slower, averaging 65 ft/day. This is attributed to the additional length of the flowpath and time required to flow from the overburden to the bedrock. Additionally, a number of the NASA traces were performed in downgradient portions of the RSA-149 groundwater unit, adjacent to the wetlands; the much lower gradients and position adjacent to the recharge boundary may account for the lower flow rates observed. The flowpaths shown on Figure 3-13 are linear from point of injection to point of dye recovery, cutting across faults and karst features. However, the actual flowpaths followed in the subsurface are likely much more tortuous and therefore longer. Consequently, the actual flow velocities are likely greater than observed assuming linear flowpaths. While the dye tracing successfully documents hydraulic connection between points of dye injection and detection, the actual flowpaths will always be beyond resolution.

As shown on Figure 3-13, the dye injections were largely made within or very near surface media site source areas. Consequently, the dye tracing serves to document that flow from the source areas is quite rapid and ongoing, such that plumes emanating from the various sources are by now well established. Additionally, the tracing documents that flowpaths between the overburden and bedrock are well connected and that both overburden and bedrock groundwater flow emerges at springs in the broad discharge area. In fact, the fastest travel times recorded were to the springs or wells that lie along mapped faults. In both the NASA and Army tracing, select monitoring locations detected more than one dye, further indicating that flow from various sources (injection locations) converge within the broad discharge area.

Dye tracing performed by NASA and the Army within RSA-147/148/149 point to another key observation regarding the length of the flowpaths. With the RSA-147/148/149 studies, the distance between the upgradient injection point and downgradient detection points ranged up to 15,915 feet (approximately 3 miles). From other studies, the traced flowpath lengths were as follows:

Source	Date	Travel Time (days)	Linear Distance		Remarks
			Feet	Miles	
GSA	08/1991	3	15,850	3.0	Shelta Cave to Brahan Spring
GSA	11/1991	10	19,800	3.8	Matthews Cave to Indian Creek at Martin Road
GSA	05/1992	8	24,816	4.7	Off post to NASA Spring
Army	03/2001	7	15,645	3.0	RSA-146 tracing

The distances reported above are direct linear distances; actual flowpath distances, which are much more convoluted, would be longer with associated higher transport velocities. These flowpath distances are significant and demonstrate that monitoring points well downgradient of a plume source or hot spot can reasonably be used for delineation.

The dye tracing documented that flowpaths in the bedrock do not honor divides mapped in the water table. Rather, flow occurs along faults or transmissive features (conduits and fracture networks) developed along faults in response to an overall north-to-south gradient. As such, bedrock flowpaths cross mapped shallow divides and groundwater unit boundaries. Dyes injected in the overburden ultimately arrived at springs and bedrock wells, and conversely, dyes injected in bedrock were detected in select overburden wells and springs. This highlights the interconnected nature of the bedrock and overburden but also that integrated flowpaths from both overburden and bedrock and shallow and deep groundwater converge to discharge at springs within the broad discharge zone. Some dyes emerged at springs located on the south side of Huntsville Spring Branch, indicating that the shallow creek is not a hydraulic boundary. However, the springs within the broad discharge zone do serve as the terminal point for flow within these units.

The dye tracing documents groundwater flowpaths connecting to springs along the downgradient fringes of the RSA-147/148/149 study area. Since the RSA-147/148/149 groundwater units occupy the central portion of RSA, further discussion is warranted to describe the nature of groundwater discharge as it also relates to the potential extent of contaminant transport within or beyond the boundary of these units.

From an RSA-wide perspective, the southern portion of the RSA-147/148/149 groundwater units marks a sharp break in topographic relief from the highlands to the north to the low-lying areas that extend farther to the south and the Tennessee River. From examination of detailed TVA pre-impoundment land acquisition maps, there were very few springs in this area prior to 1936, when Wheeler Dam was constructed. At that time, the river stage elevation was roughly 20 feet lower than present, but the dam resulted in a dramatic change to the groundwater boundary condition, which in turn caused significant flattening of the hydraulic gradient south of Huntsville Spring Branch. The lower gradient reduced the capacity of the flow system to transmit the same volume of groundwater to the river. As a result, a large number of springs emerged at the toe of slope of the topography in the vicinity of Indian Creek below Martin Road and Huntsville Spring Branch, as it was more efficient to follow overland routes.

Thermal infrared flyover surveys conducted in February 1999 identified 358 thermal anomalies indicative of groundwater discharge (i.e., apparent springs) within what constitutes a broad

groundwater discharge zone in the low-lying wetland areas along Huntsville Spring Branch and Indian Creek. Subsequent field reconnaissance performed during both winter (low pool stage/wet weather) and summer (high pool stage/dry season) conditions allowed distinction of perennial springs from ephemeral springs that only flow during the high base seasonal condition or that are inundated during the low base high pool stage. Some springs act as overflow springs, functioning only when the discharge capacity of the dominant perennial (underflow) spring is exceeded. These overflow springs are generally in proximity of the underflow springs and represent alternate pathways for discharge of groundwater to accommodate increased flow volume within the aquifer in response to a recharge event and/ or opposing head caused by stage increases in wetlands or surface water features. The thermal infrared imagery is shown on Figure 3-14, with the spring locations highlighted. The high density of springs constitutes a broad discharge zone, which is shown on the figure.

Springs within the discharge zone range from minor seeps to large-discharge volume springs with distinct drainage channels emerging from them. The majority of the large-discharge volume springs are boils emanating within wetlands or beneath surface water bodies (such as embayments of Indian Creek and Huntsville Spring Branch) with deep conical depressions formed around open orifices up to 10 feet in diameter with a slight cauliform head developed at the water surface above the spring. These springs are directly connected to or surface expressions of underlying master conduits in the subsurface.

Discharge rates at select springs have been estimated by the Army, NASA, and the USGS over the years. Overall, the reported discharge observed at any given spring ranges from 0.09 gallon per minute (gpm) to 10.5 cfs (4,705 gpm). The discharge rates represent measurements or estimations made at different times and under a wide range of seasonal (dry versus wet), stage, and antecedent rainfall conditions and further reflect differences in measurement/estimation methods by the various parties mentioned. Consequently, the available results only serve to bracket the scale of the features but are not amenable to estimating the bulk volume of groundwater discharging at any point in time or specific season.

The flow information for several key springs is described below to provide a basis for understanding of the magnitude of the groundwater discharge within the broad discharge area bounding RSA-147/148/149:

- Spring RSP-0830, which lies south of Huntsville Spring Branch and west of the Dodd Road bridge, has a spring channel that extends approximately 250 feet north to the intersection with Huntsville Spring Branch. From the thermal infrared data, the thermal signature from this spring can be seen extending from the spring to Huntsville Spring Branch and then approximately another 950 feet downstream along

the southern bank of Huntsville Spring Branch. The discharge rate from this spring at the time of the thermal infrared surveys was estimated to be 99 cfs using a thermal mixing model.

- Another large volume spring is NASA Spring (RSP-0694a), which discharges to Indian Creek just north of Martin Road on the west side of MSFC. Periodic flow measurements by the USGS from 1970 through 1992 for RSP-0694a ranged from 3.5 to 10.5 cfs (2.3 to 6.79 mgpd).

These and other similar (as well as lesser) springs constitute the broad discharge zone. In the OU-3 RI report (CH2M Hill, 2012a), it was concluded that “substantially all of the groundwater from upgradient basin areas drains to the defined discharge points within these downgradient surface water reaches.” NASA measured discharge at 14 springs within the discharge zone under low base/dry season baseflow conditions in November-December 2006 (CH2M Hill [2012a], Appendix M). The discharge measurements ranged from 0.1 to 6.26 cfs, representing a combined discharge of approximately 15 cfs, (equivalent to 9.68 mgpd) from only 14 springs during the dry season.

Theoretically, comparison of stream flow discharge in Indian Creek and Huntsville Spring Branch measured upstream and downstream of the broad groundwater discharge zone and accounting for interior runoff to these features could enable evaluation of the total volume of groundwater discharge contributing to stream flow. Unfortunately, the reaches of Indian Creek and Huntsville Spring Branch relevant to this RFI are impacted by backflow from the Tennessee River so that, although stage can be recorded, stream discharge measurements cannot be made. Although it is recognized that the bulk of the groundwater within RSA-147/148/149 discharges via springs in the broad discharge zone, attempts to quantify the volume of groundwater have proven unsuccessful.

Observed vertical gradients are another line of evidence supporting the identification of the broad discharge zone. Vertical gradients were assessed by comparing the mean water level listed in Appendix D relative to the screened interval depth at well pairs or clusters and FLUTE multiport wells located within the footprint of the broad discharge zone depicted on Figure 3-14.

Vertical gradients are upward in 9 of the 12 locations. One location was downward (MC-MWDY-006 and MC-MW00-102), but this well pair is near the NASA southwest test stand, where substructure dewatering perennially results in drawdown in the rock. Vertical gradients appear to vary in the FLUTE multiport well MW00-104D(a-f), located south of Huntsville Spring Branch at Dodd Road, along the southern boundary of the discharge zone. However, the vertical gradient is upward at MC-MW00-212D(a-f) and 154-RS1761S/D, which are also located along the southern RSA-147/148/149 boundary and south of Huntsville Spring Branch. Collectively,

the observed upward vertical gradients support the broad discharge zone which appears to serve as a boundary condition to further southward flow (and contaminant migration) in shallow and, to some degree, deep flow components. There is a potential for minor continued southerly migration into adjacent unit RSA-154, particularly with deeper, confined flowpaths.

### **3.4.3 Aquifer Geochemistry**

The geochemistry of the groundwater is a function of the recharge water and subsequent interactions between the water and the rock through which it flows. The degree of water-rock interaction is dependent on the residence time that the water is in contact with the rock and the nature of the rock and water. The residence time is a function of the rate of flow of groundwater, which is the product of the aquifer transmissivity and the hydraulic gradient. Typically, more geochemically mature waters evolve with increasing residence time (i.e., lower groundwater flow rates). Brines (saline conditions) represent the extreme endpoint in this condition, where little or no flow occurs. Since aquifer transmissivity and flow typically decrease with increasing depth, it can be expected that differing aqueous geochemical signatures are related to the geochemical maturity of the waters at various depths. Identification of discrete geochemical signatures implies distinct flow components. Alternatively, mixing of distinct water chemistries could serve as an indicator of the degree of mixing between flow components at variable depths. Field parameter data from groundwater samples serve as initial indicators of the occurrence of geochemical stratification of groundwater chemistry with depth and geographically. Additional evidence is provided by the geochemical analytical results.

Based on detailed geochemical evaluations for neighboring groundwater unit RSA-146, the following observations can be made:

- Sodium concentrations increase with increasing depth at the expense of calcium as the dominant cation.
- Bicarbonate is the dominant anion in the shallow, immature/rapid flow component but is replaced by increasing carbonate and/or sulfate and chloride with depth and as pH increases.
- The shallow flow component is almost always aerobic, reflecting the nature of the recharge water and rapid transport. Sulfate increases with depth, accompanied by increasingly reducing conditions.
- TDS concentrations increase with increasing depth and have been accompanied by increased chloride in some samples, reflecting increased residence time. An increase in specific conductance is also typically observed, which again, and in the absence of contamination, is an indicator of increased groundwater geochemical maturity.

As a result, the evolution of water types follows a progression of dominant cation-anion compositions from calcium-bicarbonate ( $\text{Ca-HCO}_3$ ) to calcium-sulfate ( $\text{Ca-SO}_4$ ) to sodium sulfate ( $\text{Na-SO}_4$ ) to sodium chloride ( $\text{Na-Cl}$ ) with increased residence time and depth. These compositions are transitional in nature and nonexclusive (i.e., exceptions are observed at various depths). Table 3-1 presents the water type for each geochemical sample for which the cation-anion charge balance is less than 15 percent. Water types are also depicted on Figures 3-3 and 3-4. The water type was derived using AquaChem software and describes the dominant cation and anion (only in the “Abbreviated” form) and the lesser cations and anions when present in milliequivalents per liter concentrations representing at least 15 percent of the water chemistry (“Full” form). While the dominant cations and anions follow the pattern described above, there are many transitional compositions.

Groundwater samples collected from the shallow and deep groundwater zones and springs at RSA-147/148/149 were analyzed for cations, anions, and field alkalinity to describe the aqueous geochemistry. These data are used to describe the water chemistry in water types defined by the predominant composition of specific cations (calcium and sodium) and anions (sulfate, chloride, bicarbonate, and carbonate). These data, combined with key field parameters (oxidation-reduction potential [Eh], pH, dissolved oxygen [DO], and specific conductance) serve to describe the aqueous geochemistry in the study area.

Plots were generated to describe the overall geochemistry presenting the field and laboratory analytical parameter results (pH, cations, anions, etc.) as a function of the depth of the midpoint of the monitored interval from which the samples were collected. Symbols used on these plots distinguish shallow (less than 120 feet bgs) from deep (greater than 120 feet bgs) and spring samples.

Figure 3-15 shows the plots of field-collected parameters (Eh, pH, DO, and specific conductance). While all zones show a broad range of values, deep groundwater shows a narrower range of values for Eh, pH, and specific conductance. DO in deep groundwater shows a range similar to that observed in the shallow zone. The principal distinction in Eh conditions is that the bulk of the shallow flow zone samples are mildly reducing (-100 millivolts or higher) to oxic, while the deeper groundwater samples tend to be more reducing (less than -100 millivolts). pH in shallow groundwater is in general more acidic than deep groundwater. Specific conductance in deep zone samples show higher values than in shallow groundwater, presumably due to longer residence time and geochemical maturity. Spring water values are similar to those for shallow groundwater.

The distribution of major cations (calcium and sodium) and TDS is shown as a function of depth on Figure 3-16. The range of calcium and sodium values in the deep zone is similar to that in the shallow zone, with no obvious trend in either as a function of depth. In contrast, the geochemical evaluation completed by NASA (CH2M Hill, 2012a) focusing principally on profiled samples from the deep FLUTE multizone wells documented a clear shift in the major cation chemistry. Similar to RSA-146, NASA observed a transition from calcium-dominated shallow water to sodium-dominated water. The depth of transition to sodium dominance was variable and location specific, ranging from 60 to 140 feet bgs. TDS concentrations show a general increasing trend with depth, further supporting the content of longer residence time and increased geochemical maturity.

Figure 3-17 shows the major anion (sulfate, chloride, bicarbonate, and carbonate) concentrations as a function of depth. The bicarbonate concentration range in the deep zone is a fairly narrow band, while the shallow zone results have a wider range. Carbonate in the shallow zone has a much broader range of values than in deep groundwater, spanning five orders of magnitude. Carbonate chemistry and the relative abundance of bicarbonate of carbonate are directly related to pH, where carbonate is the dominant stable form of alkalinity above a pH of 8.5. Sulfate and chloride concentrations increase with depth such that either or both become the dominant anions in deeper, more geochemically mature groundwater.

Although there is considerable overlap between the geochemistry of the samples designated as shallow and deep, there are subtle shifts towards increased pH, TDS, specific conductance, chloride, and sulfate with increasing depth. This is accompanied by an overall but more dramatic shift towards more reducing (i.e., negative Eh) with increasing depth. The degree of overlap between shallow and deep samples is not unexpected in part due to the arbitrary nature of the 120-foot depth distinction but also because the depth of active circulation increases along faults, which serve to allow for communication between otherwise stratabound flow zones in the interior portions of the fault blocks. As a result, water chemistry in wells along faults is more cosmopolitan due to deeper circulation and mixing with immature, fresher water.

#### **3.4.4 Depth of Active Circulation**

The geochemistry data support the RSA-wide observations regarding geochemical maturity as an indicator of relative residence time. The increasing maturity of the water with depth implies longer residence time and reduced flow. The depth below which there is no active groundwater circulation is important because the relative lack of transmissive flow zones at depth substantially limits groundwater flow and associated contaminant transport.



The depth of active circulation represents the depth above which the bulk of the groundwater flows, or circulates, and below which flow is stagnant to minimal. As described previously, the bedrock becomes less permeable with increasing depth, in part due to the lithology of the rock (chert rich) but also to the decline in transmissive feature frequency and apertures. The largest and most frequent apertures, whether fractures, solutionally enlarged fractures, or voids, occur in the upper bedrock. Consequently, it is more efficient for groundwater to follow the higher transmissivity flowpaths in the shallow bedrock. In a carbonate-dominated aquifer, this tends to increase solution, making the shallow pathways even more hydraulically efficient over time. This is not to suggest that groundwater may not be encountered in deeper bedrock, but the bulk of the flow of consequence to contaminant transport is shallow.

From previous discussions, it should be clear that the faulting provides a means of enhancing the vertical circulation of water and enhancing flowpath development at multiple levels in the aquifer. In contrast, within the fault blocks and removed from the faults, the bedrock integrity is preserved with less fracture and karstic development except perhaps in the uppermost bedrock. In these areas, groundwater flow is expected to be restricted to the shallow flow component. Given the number of fault blocks and varying position within the groundwater units (upgradient/downgradient), the depth of active circulation is expected to be quite variable.

In addition to the geochemistry described above, a number of other sources of information contribute to the understanding of the depth of active circulation. Notably, the most insight is provided from the 24 deep boreholes characterized by the Army or NASA using open-hole geophysical logging, optical televiewer logging, hydrophysical testing, and straddle packer testing. The blank liners used to limit cross contamination in the long-open holes prior to well construction provide another line of evidence. Specifically, advancement of the liner down the borehole is accomplished by filling the inside of the liner with potable water, the head of which expands the liner against the borehole wall as well as downhole. As the liner is deployed down the hole, the water that is below the advancing liner is displaced back into the aquifer. The liner advancement will continue as long as there are transmissive features in the borehole that can accept the water being forced ahead of the liner. Notwithstanding shallow liner terminations due to ledges or physical impediments, the liner will stop advancing at or near the depth below which there are no transmissive features or the head in those features is equal to the driving head within the liner.

Both the Army and NASA utilized packer testing in deep borehole characterization, but in different ways. NASA used packers to test the hole for productivity in 50-foot increments as the hole was being advanced. No records are available that document those results. The Army performed straddle packer testing of specific intervals based on the hydrophysical testing and/or

the televiewer logs. Composite plots depicting all of the borehole testing performed by the Army are provided in Appendix B-3.

The borehole characterization information and liner refusal information were used to identify the apparent depth below which there is little or no active circulation. This is summarized in Table 3-2 and shown graphically on Figure 3-18. Additionally, the base of active circulation is shown on the cross sections (Figures 3-3 and 3-4). The criteria used to identify the depth of circulation in a given borehole are as follows:

- Liner refusal depth, where not attributable to a shallow physical restriction. Note that while both NASA and the Army utilized blank liners, refusal information is not available for the NASA boreholes.
- Hydrophysical testing, specifically, the deepest observed interval which produces a response.
- Packer testing of observed hydrophysical responses, where the depth of active circulation is constrained by packer results that document that the interval will or will not produce water. Given the increasing geochemical maturity with depth, a hydrophysics response may be observed down to the markedly different (higher conductivity) water interface. Subsequent packer testing is used to verify that the zone yields water, and many times it does not.
- Geochemical signature of the water as a function of depth. Specifically, and as identified by NASA (CH2M Hill, 2012a), the transition from calcium-dominated water to sodium-dominated water has been used to distinguish active from inactive (longer residence time) groundwater. This is coupled with elevated specific conductance, pH, and/or TDS.

The pertinent information for each of these criteria is presented in Table 3-2. The depth of circulation determination is listed along with the rationale or basis for the determination. For wells installed by NASA, the base of active circulation shown in Table 3-2 coincides with the depths determined by NASA (CH2M Hill, 2012a) based on the transition from calcium-dominated to sodium-dominated water.

This evaluation reveals that there is no unique depth marking the limits of active circulation. Rather, the depth of the base of active circulation varies and is deeper along faults. The active circulation in most wells typically extends into the lower Fort Payne Formation and bedding-plane partings near the Chattanooga Shale contact but lies within the Tuscumbia Limestone at three locations. The absence of correlatable deep flow features or depth intervals is most likely due to the discrete nature of the karst flow features. From examination of Table 3-2, there is no clear pattern for the observed conditions.

From review of published reports by the GSA, it has long been recognized that the Tuscumbia Limestone and Fort Payne Chert are prolific aquifers, but only in association with highly transmissive, solution-enhanced features encountered in the uppermost bedrock. Key excerpts from the published record include the following:

- In one of the earliest reports, Johnston (1933) reported the following: “Although the calcareous rock in Alabama may contain solution openings at great depths, usually such openings do not extend far below the regional water table. Hence, it is usually uneconomical to drill deeply in calcareous rocks in exploration for water. It can be said with some assurance that if adequate water is not encountered within 150 to 200 feet of the surface a new location should be selected and a second well drilled.”
- From LaMoreaux et al. (1950): “Although the limestones may contain openings at great depths, if adequate water is not developed at a depth of 150-200 feet in the valley area in the vicinity of Huntsville, generally is more economical to select another site and drill a second well. Drilling costs increases with depth, the quality of water becomes poorer below the Chattanooga Shale, and the openings in the limestone become fewer and farther apart...An analysis of water from a well at the Roper Floral Company, 525 feet deep and developed in limestone below the Chattanooga Shale shows excessive mineral content. Water from the well contained 2,960 ppm of dissolved solids, 1,725 ppm of total hardness, and 921 ppm of bicarbonate, and 735 ppm of sulfate. The water from this well and others in the area that penetrate the Chattanooga Shale or formations below yield water having a sulfurous odor...Wells drilled below the Chattanooga Shale encounter water that is too highly mineralized for ordinary use.”
- This is reiterated by Moore et al. (1975): “Occurrence, availability, and movement of groundwater in limestone are determined by the location, geometry, altitude, and interconnections of solution openings. Most of the solution features in the Fort Payne chert occur in the upper few feet of bedrock. These solution features represent zones of downward groundwater movement along solutionally enlarged cracks and fissures in the bedrock directly below the residuum. Many of the solution features occurring below the upper few feet of the bedrock in the Fort Payne chert are oriented in a horizontal direction, denoting horizontal movement of groundwater along bedding planes or old erosional surfaces. About 60 percent of the cavities intercepted in the upper 45 feet of Fort Payne bedrock during test drilling occurred at a depth of 10 feet or less below the bedrock surface and 87 percent occurred at a depth of 20 feet or less. Solution cavities decrease in abundance with depth in the Fort Payne, so that most water in it occurs near the bedrock-residuum contact.”
- From Baker et al. (1992): “The Fort Payne chert and Tuscumbia Limestone are the principal water bearing units in the Madison area. All major wells and springs produce water from solution cavities in these formations...Groundwater in these formations moves through and is produced from these solution cavities...Further analysis of well records from the Madison area indicate that 72 percent of the solution cavities encountered occur at less than 41 feet below the top of consolidated bedrock.”

The published conclusions are based on well drilling, completion, and water production information from various geographic areas within Madison County where the formation first encountered below the overburden may be either the Tuscumbia Limestone or the Fort Payne. The statements describing the prolific nature of the Fort Payne are based on shallow wells where the Fort Payne was the first bedrock unit encountered. Within the RSA-147/148/149 units, either the upper or lower Tuscumbia Limestone is generally the first bedrock unit encountered in the subsurface. Even where the Fort Payne occurs at shallow depths (less than 100 feet), no prolific water-bearing features were observed.

As reported in the RI report for MSFC (CH2M Hill, 2012a:

- Groundwater in apertures located 5 to 150 feet below the top of bedrock ranged from a calcium/magnesium bicarbonate to calcium/magnesium-sulfate dominant water type.
- The groundwater 150 feet or more below the top of bedrock is dominated by sodium-bicarbonate, sodium-sulfate, or sodium-chloride water types.

This distribution of water types indicates that recharge water infiltrating at MSFC (or within the watershed in which it lies) circulates primarily in the residuum or the upper portions of the bedrock. The differentiation between shallow calcium-bicarbonate-rich water and deeper sodium-rich water indicates there is little or no interaction between the shallow and deeper portions of the bedrock flow system.

The published literature reinforce that active groundwater circulation is restricted to the shallow, uppermost bedrock, where karst solution features are well developed and provide the transmissivity required to convey and store water. Based on the literature and high-resolution characterization performed in RSA-147/148/149 deep boreholes, the bulk of the flow occurs within 65 feet or less of encountering the top of bedrock, diminishing below this point with increasing depth. The enhanced transmissivity in the shallow bedrock interval serves as the most hydraulically efficient pathway for groundwater (and contaminant plume) transport. Flow at greater depth through the low-transmissivity lower Fort Payne is restrictive at best and hydraulically inefficient. The published reports imply that some water may be encountered at greater depth, but the water quality diminishes as well with increasing depth.

#### **3.4.5 Groundwater Use**

Groundwater is not used as a source of potable water on post. On post, water is provided from two intakes on the Tennessee River along the southern boundary of RSA. Plant 1 (western plant) lies at river mile 323.90 and provides chlorinated potable and nonchlorinated industrial water for the installation; Plant 2 (eastern plant) lies at river mile 330.25 and provides nonchlorinated

industrial water only. A groundwater IROD further restricts exposure to or consumption of groundwater as a potable resource on RSA (Shaw, 2007a). In addition, three water supply wells provide irrigation water to the golf course within the RSA-150 groundwater unit. A fourth on-post well supplies water for a toilet. All of these wells lie upgradient of RSA-147/148/149.

Three public water supply wells are located within a 1-mile radius of RSA: the Drake and Williams wells located west of the western RSA boundary and the Triana well located near the southwestern corner of RSA. All of these wells are located in distinctly different watersheds from RSA-147/148/149, with no means of hydraulic connection. Water is also provided to off-post public consumers by the Huntsville Utilities Board and the Madison Water District. The source of the water is the Tennessee River, with the intake located upstream of RSA and the Memorial Highway Bridge.

### **3.5 Key Findings**

The following key points summarize findings regarding the hydrogeologic characterization of RSA-147/148/149 with relevance to understanding the nature and extent of contamination as well as the fate and transport of contaminants in groundwater.

- Huntsville Spring Branch and Indian Creek are the principal surface water features associated with RSA-147/148/149. Stream flow and stage vary seasonally and in response to reservoir operation-induced stage/flow conditions in the Tennessee River/Wheeler Reservoir. During high pool stage conditions (spring, summer, and fall), backflow conditions project upstream along these two streams to the Martin Road and Patton Road bridges.
- Approximately 40 percent of RSA-147/148/149 lies within the 100-year floodplain, and wetlands occupy 27 percent of the surface area. Both of these physical conditions occur along the southern and western downgradient portions of the RSA-147/148/149 groundwater units, flanking Huntsville Spring Branch and Indian Creek.
- Bedrock underlying RSA-147/148/149 includes the basal Tuscumbia Limestone, Fort Payne Formation, and Chattanooga Shale. The Tuscumbia Limestone is the uppermost bedrock unit throughout most of the study area. Regionally, a general southerly bedrock dip results in the thinning of the Tuscumbia Limestone from south to north. The southerly dip and faulting with subsequent erosion results in the Fort Payne Formation becoming the uppermost bedrock unit.
- The bedrock is highly faulted, with a series of generally north-south-trending faults cutting across all of the bedrock formations.
- The bedrock surface is highly irregular, with considerable relief due to in situ weathering and dissolution. Karst features (solution-enlarged fractures, voids, etc.) are better developed in the shallow bedrock and diminish with depth.

- Groundwater recharge occurs primarily in the winter months, when evapotranspiration is lowest.
- Groundwater within RSA-147/148/149 has been segregated into shallow and deep flow components, with a depth of 120 feet used to distinguish the two. The shallow flow component includes overburden and the uppermost bedrock, which have been documented to be hydraulically interconnected to form an unconfined, water table aquifer. With increasing depth (i.e., the deep groundwater), flow is stratabound and may be locally semiconfined to confined.
- Within the lower Tuscumbia Limestone and Fort Payne Formation, groundwater flow occurs along thin, laterally discontinuous solution features formed along bedding-plane partings and stylolites and is either confined or semiconfined. Each discrete flow zone hosts a separate head domain that may also be unique to a given fault block. Faulting presents a mechanism for hydraulic communication among otherwise isolated flow zones.
- Groundwater in the shallow water table aquifer flows in response to the gradient imposed by the mapped potentiometric surface. Within the deeper bedrock, flow is confined to semiconfined and stratabound. Dye trace studies show that groundwater flow in the bedrock does not honor the shallow water table divides (or groundwater unit boundaries derived from them) but rather follows fault-related pathways that extend for many miles across RSA-147/148/149 and into adjacent groundwater units. Dye tracing documented very rapid flow rates in the bedrock ranging from several hundred to several thousand feet per day.
- Dye tracing within RSA-147/148/149 as well as other tracing at RSA documented flowpath lengths (distance between points of injection and detection) ranging from 15,645 to 24,816 feet (2.96 to 4.7 miles). This highlights that monitoring points well downgradient and removed from a source or plume hot spot can reasonably be used to delineate the extent of contamination, particularly along faults and fractured/karstic networks developed along them.
- Dye tracing as well as tracing using contaminant distributions indicate both the shallow and deep aquifer components are hydraulically connected and discharge to springs within a broad discharge zone in the low-lying wetland area flanking Indian Creek and Huntsville Spring Branch. Dozens of high-volume springs have been identified in this area. Springs serve as the terminal discharge points from both bedrock and overburden flowpaths originating within RSA-147/148/149.
- Huntsville Spring Branch does not appear to be a boundary to flow but traverses across the broad discharge zone. Consequently, flowpaths from RSA-147/148/149 do underflow the creek, extending to wells and springs on the south side of the creek. Spring flow information, dye tracing results, and observed vertical gradients in well pairs/clusters suggest the majority of the groundwater from both shallow and deep flow components within RSA-147/148/149 comes to the surface within this broad discharge area which spans both sides of the creek. There is a potential for some

continued southerly migration into adjacent unit RSA-154, particularly along deeper, confined flowpaths.

- Differences in geochemical parameter concentrations as a function of depth and groundwater zone are apparent, indicating an increasing residence time, geochemical maturity, and more reducing conditions with depth.
- While groundwater may be encountered at any depth, active groundwater circulation is limited to the upper portions of the aquifer, where features capable of transmitting water are most abundant and best developed. The depth of active circulation does not occur at a specific depth or within a specific geologic formation but varies as a function of position relative to faults and within the groundwater units (upgradient/downgradient). The active circulation along faults may extend deeper than in areas between the faults.

## 4.0 Data Evaluation

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This chapter describes the following:

- Analytical results from environmental samples collected to determine the nature and extent of chemicals in RSA-147/148/149 groundwater
- Evaluation of data for quality and usability to support the detailed discussion of the nature and extent of chemicals in groundwater (Chapter 5.0)
- Segregation of the groundwater data into two aquifer components (shallow and deep) to provide a basis for describing the groundwater quality (nature and extent of contamination), transport, and exposure risk
- Separation of data based on investigation and delineation responsibility between the surface media sites and the RSA-147/148/149 groundwater units.
- Examination of analytical methods to ensure that detection limits (DL) are adequate to support meaningful comparison of analytical results with regulatory evaluation criteria
- Determination of chemicals that exceed one or more evaluation criteria to guide discussion of their nature and extent.

### 4.1 Data Sets

The environmental samples used to characterize RSA-147/148/149 groundwater were collected from multiple investigations, as summarized in Chapter 2.0. Investigation of the RSA-147, RSA-148, and RSA-149 groundwater units included the collection of groundwater, surface water, and sediment samples to characterize the unit. Spring, monitoring well, and hydropunch groundwater, surface water, and soil vapor sample locations within RSA-147/148/149 are shown on Figures 2-3 through 2-7. Supporting field records for Army sampling locations are included for reference in Attachment 2. They provide additional information regarding the sample locations (e.g., boring and well construction logs) and the samples collected (e.g., sample collection logs). Analytical results are included electronically in Appendix F-1.

In Appendix F-1, the data file *RSA\_147-148-149\_Data\_All.xlsx* is a comprehensive report of all available analytical results, field parameters, and data usability issues associated with the RSA-147/148/149 sample locations. Separate worksheets in that file present the following data:

- **GW:** Definitive data from the analysis of groundwater samples collected from monitoring wells and from the throats of springs (prior to discharge into surface water).



- **HYPN:** Screening-level data from the analysis of groundwater grab samples collected from piezometers and temporary wells.
- **SW:** Surface water data from samples collected in streams and wetlands, including samples collected immediately above or adjacent to springs (discrete groundwater discharge points).
- **SD:** Sediment data from samples collected in streams and wetlands, including samples collected at or adjacent to springs (used to support the screening-level ecological risk assessment [SLERA], as described in Chapter 7.0).

The file *RSA\_147-148-149\_Data\_Usable.xlsx* is also included in Appendix F-1. This data file includes only those data determined to be usable for this RFI, based on the usability evaluation described in Section 4.2.

## **4.2 Data Quality and Usability Considerations**

The environmental samples used to characterize RSA-147/148/149 were collected from multiple investigation activities, as summarized in Chapter 2.0. Data from the analysis of those samples were evaluated to determine their usability and suitability in meeting the objectives of this RFI, which are presented in Section 1.7.

A primary objective of the RFI is to identify and delineate the nature and extent of chemicals in groundwater. Surface water is also evaluated because groundwater discharges directly to surface water bodies through springs. Data from investigations of surface media sites indicate that plumes of chemicals in RSA-147/148/149 groundwater have developed beneath surface media sites where past releases contributed sufficient source material. Concentrations of site-related chemicals in these plumes are either generally stable or declining. This RFI report addresses the present-day nature and extent of site-related chemicals by focusing on recent analytical data from January 2007 through May 25, 2017.

**Data Evaluation Process.** Evaluating data quality includes the following steps:

- Review the validation process to ensure accordance with standard protocols and that data flagged as unacceptable are not used in the decision-making process.
- Verify the adequacy of analytical methods.

Evaluating data adequacy and usability includes the following steps:

- Determine the usability of historical and current data for their intended use and identify suspect or obsolete sampling methods, inappropriate equipment, or site-specific factors that render samples nonrepresentative or adversely affect analytical results.

- Evaluate the locations of historical samples with respect to the current site boundary to assure that data are relevant, giving consideration to release points, transport mechanisms, and transport pathways.
- Determine whether the number and distribution of samples used in the decision-making process are adequate to determine the nature and extent of contamination.

Sections 4.2.1 through 4.2.3 discuss the data quality and data usability evaluations for analytical results associated with RSA-147/148/149.

**Evaluation Criteria.** Evaluation criteria include established installation-wide background screening values (BSV) for metals and various indices developed by ADEM and EPA. BSVs have not been developed for perchlorate, although this chemical occurs naturally under some circumstances (Trumpolt et al., 2005).

Metals are naturally occurring constituents of soil and rock, and many are ubiquitous. Therefore, it is essential to compare concentrations of metals in the site-specific analytical data set against concentrations that would be expected in unaffected (background) media at RSA. Background data sets and background screening values for groundwater (IT Corporation [IT], 2002) and surface water (Shaw, 2008b) were accepted by ADEM and EPA. These values are included in the analytical data reports provided in Appendix F-1 and used to evaluate groundwater and surface water in accordance with the established site-to-background comparison procedure (Shaw, 2003b). Data obtained from background surface water locations on the upstream facility boundary are excluded from the site-to-background comparison.

EPA has published screening values based on health and environmental risks associated with many of the organic and inorganic chemicals found in the environment at RSA. Groundwater and surface water analytical results are compared to preliminary screening values (PSV), with the exception of data from background sample locations where streams enter the facility.

The RSA-specific PSVs for groundwater are based on the following hierarchy:

- Maximum contaminant level (MCL) from EPA (2012) unless superseded by ADEM-specific value
- The health advisory level for perchlorate (DoD, 2009)
- EPA (2017) tap water regional screening level (RSL) based on cancer risk of 1E-6 or adjusted downward to reflect a noncancer hazard index (HI) of 0.1.

For site-related chemicals in groundwater with no PSVs, surrogate values are estimated by the EPA (2014) RSL methodology using available toxicity and physical property data and adjusted as described above.

It is important to note three points regarding MCL application, two technical and one policy based. MCLs were not developed to be used in a contaminant-screening capacity. MCLs are not always risk based and are rather based on technical practicability. It should be noted that the Army does not normally use MCLs in a contaminant-screening capacity. However, MCLs were used in the subject assessment in order to comply with AEIRG and ARBCA guidance. RSA is legally mandated to comply with the AHWMMMA. In RSA's AHWMMMA Permit, ADEM requires that these guidance documents be adhered to during environmental investigations and evaluations.

The PSVs for surface water as designated by ARBCA are chosen by the following hierarchy:

- Alabama water quality standards based on human health water quality criteria (WQC) for consumption of drinking water and aquatic organisms (State of Alabama, 2014). The value for arsenic is at a cancer risk level of  $1 \times 10^{-5}$ , as cited in the Administrative Code.
- National water quality standards based on WQC for human health consumption of water and organisms (EPA, 2014).
- Groundwater/tap water PSVs determined as described above.
- EPA ecological screening values (ESV) for surface water.

The PSVs are included in the analytical data reports (Appendix F-1). Each result is compared to the BSV (for metals), PSV, and ESV (for surface water), documented as the factor by which the threshold index is exceeded.

#### **4.2.1 Data Quality Evaluation**

All RFI data were collected, stored, and managed in accordance with the installation-wide quality assurance program plan (QAPP) (Shaw, 2010b). Samples collected were analyzed using approved EPA SW-846 Update III methods (or most recent version) and laboratory standard operating procedures as presented in the quality control summary report (Appendix F). For data collected prior to 2010, quality control procedures followed the U.S. Army Corps of Engineers (USACE) Savannah District data reporting and evaluation Level C and the guidance provided in *Shell for Analytical Chemistry Requirements* (USACE, 1998). For samples collected from 2010 through 2014, quality control procedures followed the DoD Quality Systems Manual, Version 4.2 (DoD, 2010). For samples collected beginning in 2015, quality control procedures followed

the DoD Quality Systems Manual, Version 5.0 (DoD, 2013). All sample data generated were reviewed and verified by the laboratory personnel prior to reporting following the appropriate guidance document.

All data from the laboratories are reported to three significant figures. Printed reports received from the laboratories reflect this level of accuracy. However, due to the inability of Microsoft® Excel to control significant figures without displaying the data in scientific notation, data are presented within this RFI report as received electronically by the laboratories.

Analytical data were provided by the laboratories in print and electronic formats and incorporated into the Redstone Central Data Repository. Complete raw data packages contain all the necessary information for generation of definitive data. Electronic data comply with all Redstone Central Data Repository reporting requirements.

Electronic data loaded into the Redstone Central Data Repository and verified using the data-loading module. Hard copy data were reviewed and validated using the DoD Quality Systems Manual, Version 5.0 for guidance. EPA *Region 3 Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Organic Analyses* (EPA, 1994) and *Region 3 Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses* (EPA, 1993) are applied during the blank evaluation portion of the validation activities. Specific quality control criteria identified in the installation-wide QAPP (Shaw, 2010b), analytical methods, and laboratory standard operating procedures are applied to all sample results. For those analytical methods not addressed by the validation guidelines, the evaluation is based on the published method requirements, laboratory-specific standard operating procedures, and technical judgment following the logic of the Contract Laboratory Program validation guidelines for data qualification.

For those analytical methods not addressed by the Contract Laboratory Program guidelines, validation was based on the published method requirements, laboratory standard operating procedures, and technical judgment. The data quality evaluation and usability determinations were performed using the resulting validation information, and all associated data were qualified accordingly. Results for constituents determined to be present in field samples associated with contaminated field or laboratory blanks were qualified with “UB” validation flags (by application of the 5 times/10 times rule). The results of validation are reported along with the analytical data provided in Appendix F-1.

The data quality evaluation and usability determinations were performed using the resulting validation information, and all associated data were qualified accordingly. The quality control

summary report (Appendix F-2) presents results of the quality control measures implemented during sampling and analysis and contains validated analytical data relevant to RSA-147/148/149.

#### **4.2.2 Data Usability Evaluation**

The RSA-147/148/149 data set includes screening-level data and definitive data. Screening-level data are typically unvalidated and include groundwater grab samples collected from piezometers, soil borings, and open borehole intervals isolated by inflatable packers. Other results not subject to validation are also considered screening-level data, including field analyses (ferrous iron, alkalinity, sulfate, etc.) and bacteria population analyses (DHC). Definitive data are validated and include results from samples collected in accordance with standard procedures from spring throats, purged monitoring wells, and surface water locations.

Data presented in this RFI report were evaluated to ensure they are defensible and representative. The data usability evaluation ensures that appropriate data are used for characterizing the site and assessing potential risks to human health and the environment. Standard decision criteria used to evaluate the analytical results are consistent with numerous RSA reports over the past decade.

Decision criteria applied during the evaluation of data for use in this RFI include, but are not limited to, the following:

- Definitive, validated data obtained from spring throats and from groundwater sampling at monitoring wells are used. Groundwater data collected since 2007 are considered most representative of current aquifer conditions and are the primary data considered to characterize groundwater conditions.
- Screening-level groundwater samples were only used in nature and extent mapping, and then only nondetect results or detected results at concentrations below the PSVs were used. Such data are not typically validated but do serve to support delineation of the extent of contamination, in conjunction with definitive, validated results described above.
- Metals data from groundwater samples with high turbidity (typically above 100 nephelometric turbidity units) or lacking turbidity measurements are generally considered unusable.
- Metals data from filtered groundwater samples are not considered representative of potentially potable groundwater and are not used in this RFI, per Appendix C, paragraph C.4.3 of the AEIRG. However, perchlorate data from filtered groundwater samples are usable. Perchlorate represents a special case where, in accordance with EPA Method 6850, whenever possible, water samples should be sterilely filtered in the field at the time of collection using 0.2-micrometer polytetrafluoroethylene membrane to remove perchlorate-degrading microbes.

- Surface water samples collected from 2007 to present were also evaluated for usability, and usable results are included in this report for completeness.
- Only validated data are used in risk evaluations, in accordance with regulatory requirements.
- Groundwater and spring results from within the MSFC were used where necessary in defining the nature and extent of contamination within areas of groundwater unit responsibility. Such data are depicted on maps in similar fashion to other data and are included in order to provide a complete picture of the current nature and extent of contamination. However, with the exception of MSFC-034 and in accordance with the MOA between the Army and NASA, groundwater within MSFC is the sole responsibility of NASA. Consequently, analytical data for groundwater and surface water sampling locations within MSFC are graphically depicted but not otherwise evaluated further in this RFI.

All data usability decisions are intended to ensure the use of data that support defensible decisions. Sample usability is documented in the data file *RSA\_147-148-149\_Data\_Usable.xlsx* (Appendix F-1). This file includes only those results determined to be usable for characterizing groundwater conditions, including results qualified as screening data. Data collected by both the Army and by NASA are available for use in finalizing this RFI. NASA data include results from locations within MSFC as well as beyond the MSFC boundary. With the exception of data collected by either source within MSFC-034, all other data within MSFC were considered unusable. The following table summarizes the total number of sampling locations and samples collected by source (Army or NASA), and the resultant number of samples determined through this evaluation to be usable.

			Army Data		NASA/MSFC Data	
			All Army Data	Usable Army Data	All NASA Data	Usable NASA Data
			Locations/Samples	Locations/Samples	Locations/Samples	Locations/Samples
Groundwater	Shallow	Springs <sup>a</sup>	50 / 77	48 / 58	16 / 549	16 / 231
		DPT	460 / 499	454 / 483	610 / 717	607 / 707
		Mon. Wells <sup>a</sup>	839 / 3629	783 / 2246	323 / 3515	215 / 1527
	Deep	Deep Wells <sup>a</sup>	80 / 249	76 / 136	49 / 660	48 / 576
Surface Water Samples			278 / 332	81 / 95	125 / 300	13 / 67
Soil gas (vapor intrusion)			8 / 8	3 / 3	42 / 42	2 / 2

Of the extensive data set represented by the groundwater and surface water samples shown above, only the most recent result of the usable samples (by parameter) collected from locations that lie within the area defined as the Army's responsibility are considered representative of current conditions.

### **4.3 Groundwater Vertical Zones**

Groundwater has been segregated into two populations to support the evaluation of vertical contaminant distribution in RSA-147/148/149 groundwater. Two zones are defined: shallow and deep. All of the groundwater evaluations presented in this RFI utilize these two zonal groupings.

#### **4.3.1 Shallow**

Groundwater within the overburden, overburden/bedrock interface, and upper bedrock zones to a depth of 120 feet bgs is considered collectively as shallow groundwater. All three zones are hydraulically interconnected through an epikarstic interface and bedrock fractures and conduits, and from the shallow, unconfined water table aquifer. Additionally, groundwater emerging from springs is categorized with the shallow groundwater component, although deep groundwater also emerges from springs within these units.

#### **4.3.2 Deep**

Bedrock groundwater from depths of more than 120 feet bgs is considered deep. Hydraulic interconnections exist between shallow and deep groundwater, and both zones comprise a single aquifer. However, as described in Chapter 3.0, with increasing depth, the features and zones hosting groundwater become semiconfined to confined. Hydraulic connections between shallow and deep groundwater flow components principally occur along mapped faults. The 120-foot depth threshold is arbitrary but serves as a reasonable cutoff which is consistent with presentation in RFI reports for other groundwater units.

### **4.4 Separation of Data Based on Groundwater Responsibility**

As discussed in Section 1.6, in most cases, surface media sites are responsible for the investigation and delineation of groundwater contamination underlying them. The focus of this RFI is to define the nature and extent of contamination within the few areas not addressed by active surface media site investigations or ongoing corrective measures. Areas not addressed by surface media sites are the responsibility of the RSA-147/148/149 groundwater units. As previously discussed, the groundwater units are responsible for 15 active sites and 11 sites currently categorized as NFA (Table 1-3). To complete the evaluation of these areas, it is necessary to establish which groundwater and surface water sampling locations are positioned within the scope of surface media site-responsible areas and which lie within areas of groundwater unit responsibility. The process for assigning responsibility of the sampling locations to either the surface media sites or to the groundwater units is as follows:

- 1) Determine the SWMUs and areas of concern where groundwater is the responsibility of an individual surface media site or group of sites (based on information summarized in Table 1-1 and presented as Figure 1-5).

- 2) Determine those areas where groundwater is the responsibility of the groundwater units (based on information summarized in Table 1-1 and presented as Figure 1-5).
- 3) Tag sampling locations within each of the areas identified in Steps 1 and 2 to classify it as being the responsibility of the surface media sites or the groundwater units.

From Steps 1 and 2, above, and Figure 1-5, responsibility areas and sampling location assignments are presented as Figure 4-1. Investigation areas shown on Figure 4-1 include those areas where delineation of groundwater contamination is assigned to surface media sites and NASA. In order to determine possible impacts, NASA is currently monitoring groundwater, surface water, and sediment in off-site areas included in the Indian Creek watershed where contamination associated with NASA sources has migrated. Several removal actions have already been completed by NASA to address PCB contamination in the Indian Creek watershed. Remaining areas are the responsibility of the groundwater units and include the Northern Disposal Area (NDA) at RSA-053, the areas surrounding RSA-057 and RSA-122 (including RSA-056 and RSA-139), the RSA-183 area (including the drainage area/sinkhole), and remaining areas not defined as the responsibility of surface media sites. Responsibility assignments are also carried forward to the analytical data files presented in Appendix F-1; in those files, a column labelled “*Responsibility*” labels those data from locations that are the responsibility of the groundwater units as “GW”; all other locations are identified as “Other.”

To further refine the areas where groundwater contaminant delineation is required, it is necessary to identify those sampling locations where PSVs are exceeded in most recent, usable samples. These locations are presented as Figures 4-2 and 4-3 for the shallow and deep flow zones, respectively. Sampling locations are color coded to show both PSV exceedance and responsibility assignment. From Figures 4-2 and 4-3, six specific areas where the groundwater units are responsible for contaminant delineation can be established. These six areas are defined as groundwater focus areas (FA). The six FAs are presented as Figure 4-4. Four of the FAs align with SWMUs where groundwater delineation is assigned to the groundwater units. Two FAs encompass areas of identified groundwater contamination that are not the responsibility of a surface media site. The six groundwater FAs include the following:

Focus Area	SWMUs or Areas Included
FA-1	RSA-057
FA-2	RSA-122, and around RSA-056, and RSA-139
FA-3	Area surrounding 147-RS1972
FA-4	RSA-053 (NDA only)
FA-5	RSA-183 and drainage area/sinkhole
FA-6	Area surrounding 148-RS1986



The nature and extent of contamination within these six FAs is presented in Chapter 5.0.

#### **4.5 Adequacy Evaluation of Analytical Methods**

This section presents discussion and comparison of achieved DLs with PSVs for RSA-147/148/149.

Guidance on sampling and analysis of environmental media is provided largely in the ADEM (2017b) AEIRG. This guidance requires that samples be analyzed using analytical methods capable of achieving DLs that are lower than associated PSVs for chemicals that are in the CSM of a site. Note that ADEM guidance refers to DLs as method detection limits.

In September 2014, the Army's subcontracted analytical laboratories initiated the use of refined analytical methods that can reliably achieve PSVs for all but a small number of chemicals in groundwater. However, prior to this time, analytical methods were unable to reliably meet current PSVs for over 30 compounds in soil and groundwater. As discussed at the Compliance Assistance Meeting held on November 13, 2014 and summarized at the Compliance Assistance Meeting held on June 26, 2015, with clarification based on discussions at the February 16, 2017 Compliance Assistance Meeting, the Army will use the approach discussed below to evaluate the adequacy of DLs compared to PSVs.

Sample-specific DLs are presented in the Geographic Information System (GIS) Excel data file located on the compact disk (CD) deliverable included with this RFI report. Terminology has changed over the more than 30 years of environmental investigations at RSA. Therefore, in the RSA database and the GIS Excel file on the CD deliverable, DLs are located in the column entitled "DL." PSVs are also included in the GIS Excel data file, typically in the column entitled "PSV\_2017." The DLs rather than the reporting limit (also called the limit of quantitation) are the analytical limit that should be compared to the PSV. For metals, the DLs must be less than the greater of the BSV or PSV. Only site chemicals of potential concern (COPC) that are in the CSM are required to have DLs less than the PSV.

Note that there is no value added in evaluating DLs for detected values. Therefore, in the GIS Excel data file, any results with a data flag of "Y" in the column labeled "DETECT" were not included in the evaluation of whether DLs were greater than PSVs. When using the GIS file, the "filter" function can be used to filter out detected results in order to prevent inaccurate results. In addition, it is important to understand that not all samples listed in the GIS Excel data file will have DLs less than PSVs. ADEM has requested that all historical and current site-related data be included in GIS Excel files. Historical results may not have DLs less than PSVs but often these data are not considered representative of current site conditions. The data considered usable for

characterizing nature and extent are identified in this RFI report in GIS Excel file on the CD deliverable, and these are the samples used to determine if DLs for COPCs exceed associated PSVs.

There are four chemicals in groundwater for which PSVs are so low that laboratories (as of 2017) are not able to achieve DLs less than PSVs. These chemicals are aldrin, bis(2-chloroethyl)ether, n-nitroso-di-n-propylamine (NDPA), and 1,1-dimethylhydrazine. Resampling and reanalysis using more sensitive methods are not possible for these four compounds even if they are in the CSM of the site.

When samples with DLs greater than PSVs for site COPCs are present and impede decision making, the Army will address this issue whenever possible by resampling. However, this may not be possible. Not every sample will be able to achieve DLs less than PSVs for a number of reasons which may preclude reanalysis. Examples of situations in which DLs may exceed PSVs in current samples include:

- Matrix interferences require the sample or sample extract to be diluted, which increases the DLs. Sample-specific DLs will be elevated and may not be less than PSVs.
- Samples analyzed at a dilution because of high concentrations of other chemicals. Often in the area of a release, laboratories must analyze samples at a dilution in order to keep the sample response within the calibration range and to protect their instrumentation. Doing so raises the DLs for all constituents in the sample. Altering methods will not resolve this sample-specific issue.

In many cases, situations where DLs may exceed the PSVs will not affect site decision making. Examples of such situations are as follows:

- The given chemical is not in the CSM for the site.
- The exceedances are limited to a few samples and the majority of the results are detects or nondetects for which the DL meets the PSV.
- The locations of the exceedances are not in the known source areas or areas likely to be impacted by the chemical of interest.

The results of the comparisons of sample-specific DLs compared to PSVs for groundwater are presented in Table 4-1.

#### **4.5.1 Summary of Conceptual Site Model**

The RSA-147/148/149 area comprises 3 of the 13 groundwater units at RSA and covers 8,792 acres in the central portion of the facility. Chemicals released during historical activities at

surface media sites, including those within MSFC, contaminated groundwater within these groundwater units. The Army is responsible for groundwater associated with MSFC-034. In accordance with MSFC's FFA, responsibility for MSFC's OU-3 groundwater remains with NASA. Several investigations have been performed for the RSA-147/148/149 groundwater units (Section 2.9).

A brief description of the groundwater units and COCs identified in previous RFIs are summarized below.

**RSA-147 (FAs 1, 2, and 3).** The Phase 2b RFIs conducted in RSA-147 focused on surface media sites RSA-117 and RSA-054/055. The COCs associated with both RSA-117 and RSA-054/055 include VOCs, pesticides, PCBs, and metals.

**RSA-148.** The Phase 2b RFIs completed in groundwater unit RSA-148 focused on surface media sites RSA-061 and RSA-183. The COCs associated with RSA-148 groundwater unit include VOCs, SVOC (including PAHs), pesticides, PCBs, explosives, metals, and agent breakdown products (thiodiglycol and thianes). Perchlorate was analyzed in earlier groundwater samples but was either nondetect or below the health advisory level. Therefore, perchlorate was not included in the analytical suite for the most recent groundwater sampling.

**RSA-149.** The COCs associated with RSA-149 groundwater unit Phase 2b RFI investigation include VOCs, metals, and agent breakdown products (thiodiglycol and thianes).

Additional fieldwork was conducted from October 2016 to February 2017 for the supplemental Phase 2c RFI. The investigations were intended to specifically focus on sites and plumes for which the groundwater units hold the responsibility for groundwater.

The principal contaminants present in RSA-147/148/149 groundwater are VOCs (chiefly TCE, 1,1,2,2-tetrachloroethane [TeCA], chlorobenzene [CBZ], carbon tetrachloride [CT], and tetrachloroethene [PCE]) and pesticides, with additional impacts from SVOCs, explosive compounds, PCBs, and metals.

The major facilities and activities performed on the surface media sites overlying RSA-147/148/149 are summarized in Sections 1.5.1 through 1.5.3. Chemicals potentially associated with these facilities and activities include perchlorate; organochlorine pesticides (OP); and wide varieties of metals, SVOCs, PCBs, explosive compounds from manufacturing and disposal of explosives, and VOCs.

#### **4.5.2 Results of Evaluation**

##### ***Nondetects in Groundwater Samples***

The maximum analytical DLs for chemicals in RSA-147/148/149 groundwater were above associated PSVs for 6 explosives, 2 OPs, 19 SVOCs, and 34 VOCs (Table 4-1).

Aldrin and NDPA were identified in Section 5.3 as chemicals in groundwater for which PSVs are so low that laboratories are not able to achieve DLs less than PSVs. Aldrin was detected in two groundwater samples and therefore was included in the screening-level risk evaluation. NDPA was not detected in any groundwater sample, but the maximum DL exceeded the PSV in only two samples.

**Explosives.** Six explosive compounds had DLs that exceeded their respective PSVs. 2,4-DNT and 2,6-DNT were analyzed as explosives as well as SVOCs. The DLs for samples collected in 2016 and 2017 did not exceed the PSVs for both explosive and SVOC analysis. Likewise, the 2016 and 2017 DLs for the other four explosive compounds did not exceed their PSVs. Because no chemicals with maximum DLs were greater than their PSVs in current groundwater samples, no further evaluation of nondetect explosive chemicals in groundwater samples is necessary.

**Pesticides.** The maximum DLs for dieldrin for samples collected in 2017 did not exceed the PSV. As discussed above, laboratories are not able to achieve DLs less than the PSV for aldrin. Therefore, no further evaluation of nondetect pesticide chemicals in groundwater samples is necessary.

**SVOCs.** Nineteen SVOCs had maximum DLs that exceeded their respective PSVs. With the exception of two DLs for NDPA, the maximum DLs for all SVOCs in the most current groundwater samples did not exceed their respective PSVs. The DL exceedances were from historical results before the use of refined analytical methods. In addition, the maximum DL of nitrobenzene did not exceed the PSV when analyzed under the explosive method. Because most of the chemicals in current groundwater samples had maximum DLs less than their PSVs, no further evaluation of nondetect SVOC chemicals in groundwater samples is necessary.

**VOCs.** VOCs are in the CSM for all three groundwater units. Extremely high concentrations of TCE, CBZ, and CT resulted in samples analyzed at varying dilution factors of 10, 20, 25, 50, 100, 500, and 1000. However, as can be seen in Table 4-1, in most cases the number of nondetect DLs that exceed the PSV is low. Exceptions include 1,1,2,2-TetraCA and bromomethane. However, these two VOCs were detected and therefore included in the risk evaluation. In addition, the DLs in current groundwater do not exceed their PSVs except for four samples with a dilution factor of 2. Because only a small percentage of DLs exceeded their respective PSVs

and most of the VOCs were detected and included in the risk evaluation, no further evaluation of nondetect VOC chemicals in groundwater samples is necessary.

#### **4.5.3 Frequently Encountered Initial COPACs at RSA Sites**

Several chemicals identified as chemicals of potential analytical concern in the installation-wide QAPP (Shaw, 2013b) frequently are not detected in soils and/or groundwater at a given site but may have DLs greater than their PSVs. Those potentially relevant to RSA-147/148/149 are listed below, with data regarding their applications and uses summarized from their Agency for Toxic Substances Disease Registry toxicological profiles

(<http://www.atsdr.cdc.gov/toxprofiles/index.asp>), from the National Library of Medicine's

Hazardous Substance Data Bank (<http://toxnet.nlm.nih.gov/newtoxnet/hsdb.htm>), and/or from their International Agency for Research on Cancer monographs

(<http://monographs.iarc.fr/ENG/Monographs/PDFs/index.php>). The use and application data are helpful to determine whether the following chemicals are within the CSM of RSA-147/148/149:

- **2,4,6-Trichlorophenol.** 2,4,6-Trichlorophenol is used as a bactericide; in the leather, pulp, and wood industries; in the manufacture of a fungicide and a bleaching agent; and as a defoliant, herbicide, and fungicide.
- **2,4-Dinitrophenol.** 2,4-Dinitrophenol is used in the production of dyes, explosives, and photographic developer and was formerly used as a weight-loss drug.
- **3,3'-Dichlorobenzidene.** 3,3'-Dichlorobenzidene is used largely as an intermediate in the manufacture of pigments and dyes and in plastic and rubber formulations.
- **4,6-Dinitro-2-methylphenol.** 4,6-Dinitro-2-methylphenol was formerly used as an insecticide and miticide (particularly in orchards) and in dye production and currently sees limited use as a wood preservative and in styrene production.
- **4-Chloroaniline.** 4-Chloroaniline is primarily produced and used as an intermediate for the synthesis of dyes, pharmaceuticals, and agricultural chemicals. It can also be present in soil as a result of the use of phenylurea herbicide, of which it is a degradation product.
- **4-Nitroaniline.** 4-Nitroaniline is used as an intermediate in the synthesis of dyes, antioxidants, pharmaceuticals, and the fungicide 2,6-dichloro-4-nitroaniline.
- **Dibenzofuran.** Dibenzofuran is present in coal tar and heat-transfer oils. It is also used as a carrier for dyeing and printing textiles, as an intermediate in dyes, and as an antioxidant in plastics.
- **Hexachlorobenzene.** Hexachlorobenzene was formerly used as a fungicide and as an intermediate in a wide variety of organic synthesis reactions including pesticides. It was used in the production of smoke munitions for the military, but not at RSA.

Smoke munitions at RSA used hexachloroethane (see below). Hexachlorobenzene was also a contaminant in several chlorinated substances that had previously been used in large quantities but are no longer produced or used, such as the pesticides mirex and lindane and the solvent CT.

- **Hexachlorobutadiene.** Hexachlorobutadiene is used primarily as an intermediate in the production of rubber. Lesser quantities are used as an intermediate in production of solvents, chlorofluorocarbons, and lubricants; as a solvent for elastomers; in fluids for heat transfer, gyroscopes, and hydraulics; and internationally, as a fumigant for grapes.
- **Hexachloroethane.** Hexachloroethane production and use includes inorganic synthesis, as a camphor substitute in nitrocellulose, in the manufacture of smoke pots and grenades, and in metallurgical activities.
- **NDPA.** NDPA is produced intentionally only in laboratory-scale quantities for experimental purposes. NDPA may be produced as an impurity in the trifluralin, isopropalin, and oryzalin herbicides, but the concentration of NDPA is regulated and thus would not be present at toxicologically significant concentrations from herbicide use (federal regulations require trifluralin formulations to contain less than 0.5 part per million NDPA [EPA, 1996]). NDPA is not a contaminant or breakdown product of explosives.
- **Pentachlorophenol.** Pentachlorophenol is used predominantly as a heavy-duty wood preservative, pesticide, and specialized disinfectant and was widely used as an insecticide, fungicide, herbicide, algicide, disinfectant, and ingredient in anti-fouling paint before mid-1984.
- **1,1,2,2-TeCA.** 1,1,2,2-TeCA is a degreasing agent that has been used along with other chlorinated solvents on some RSA sites. However, this chemical also occurs as an impurity in commercial grade TCE. Acetylene tetrachloride (1,1,2,2-TeCA) was also a component of a decontaminating process for mustard gas.
- **Bromomethane.** Bromomethane was formerly used as an insecticide, acaricide, nematocide, rodenticide, and soil sterilant. Its use has been phased out in the United States.
- **cis- and trans-1,3-Dichloropropene.** cis- and trans-1,3-dichloropropene are largely produced and used as a soil fumigant and nematocide.

#### 4.5.4 Conclusions

Samples included in the evaluation were collected from 2008 through 2017. Because of the age of data and analytical methods used at the time, many of the DLs exceeded their respective PSVs. In addition, many elevated DLs were due to dilution. However, the DLs for the most recent groundwater samples collected in 2016 and 2017 are below their PSVs, demonstrating the adequacy of the analytical methods for current conditions. The evaluation concluded that no

chemicals were identified in groundwater for further evaluation based on adequacy evaluation of analytical methods.

#### **4.6 Chemicals Detected**

This section summarizes information regarding all chemicals detected in the most recent samples collected from all RSA-147/148/149 groundwater and surface water sampling locations, regardless of nature and extent delineation responsibility. Chapter 5.0 describes the nature and extent of chemicals that exceed the PSVs within the groundwater unit-responsible areas. The site-to-background comparison (Appendix G) determines which metals detected in groundwater or surface water with concentrations greater than their BSVs and PSVs may be site-related chemicals.

##### **4.6.1 Chemicals in Groundwater**

RSA-147/148/149 groundwater samples were analyzed for TCL VOCs, TCL SVOCs, pesticides, PCBs, explosive compounds, perchlorate, TAL metals, and other miscellaneous and general chemistry parameters. Table 4-2 lists chemicals analyzed in RSA-147/148/149 groundwater, along with their frequencies of detection and exceedance, which are the ratios of the number of results greater than the PSV (and BSV for metals) to the number of samples analyzed. This elementary statistical information highlights the chemicals that are the most prevalent in RSA-147/148/149 groundwater. In Table 4-2, the chemicals listed at the top of each parameter group (e.g., VOCs, pesticides, etc.) are those that have PSV (and BSV for metals) exceedances, listed in order of decreasing frequency of exceedance.

As discussed above, metals are evaluated separately (and on a groundwater units-wide basis) in Chapter 5.0 and Appendix G to determine if detected concentrations represent site-related contamination or naturally occurring background levels.

##### **4.6.2 Chemicals in Surface Water**

RSA-147/148/149 surface water samples were also analyzed for TCL VOCs, TCL SVOCs, pesticides, PCBs, explosive compounds, perchlorate, TAL metals, chemical agents, and other miscellaneous and general chemistry parameters. All surface water sampling locations are determined to be the responsibility of surface media sites. One surface water sampling location lies within FA-4, but no contamination has been identified at that location.

Table 4-3 lists chemicals analyzed in RSA-147/148/149 surface water, along with their frequencies of detection and exceedance, which are the ratios of the number of results greater than the PSV (and BSV for metals) to the number of samples analyzed. This elementary statistical information highlights the chemicals that are the most prevalent in RSA-147/148/149

surface water. In Table 4-3, the chemicals listed at the top of each parameter group (e.g., VOCs, pesticides, etc.) are those that have PSV (and BSV for metals) exceedances, listed in order of decreasing frequency of exceedance.

As shown in Table 4-3, 20 nonmetal chemicals and 6 metals were detected in RSA-147/148/149 surface water samples at least once at concentrations that exceed their PSV (and BSV for metals). These compounds and metals were also detected in RSA-147/148/149 groundwater samples. Metals are evaluated separately in Chapter 5.0 and Appendix G to determine if the detected concentrations represent surface media site-related contamination or naturally occurring background levels.

#### **4.7 Surface Water Areas**

RSA-147/148/149 groundwater discharges into streams and wetlands as diffuse flow through the beds of water bodies and as more concentrated flow through springs. Chemicals transported from surface media sites by groundwater that is discharged to water bodies have the potential to degrade surface water and sediment. Potential threats posed by chemicals in RSA-147/148/149 groundwater to populations of ecological receptors are evaluated in Chapter 7.0. Within the RSA-147/148/149 boundary, surface water has been grouped into three subareas for the subsequent evaluations in this report:

- Subarea 1, Indian Creek
- Subarea 2, Huntsville Spring Branch
- Subarea 3, RSA-122 Stream.

Surface water and sediment were sampled at key locations within each subarea, as described in Sections 4.7.1 through 4.7.3. When groundwater samples were collected from within a spring's throat (prior to mixing with surface water), surface water and sediment samples were also collected. A surface water sample (and sediment, where present) was collected where the spring discharges at the surface. Typically, an additional surface water and sediment sample was collected approximately 10 and 20 feet downstream of the spring. The downstream locations were sampled to evaluate attenuation of chemicals discharged from springs as they move downstream in surface water. Each downstream location shares the sample location code assigned to the spring, but the code has an "x" or "y" appended to indicate collection at a nominal distance (approximately 10 and 20 feet downstream of the spring, respectively).

The SLERA (Chapter 7.0) evaluates surface water and sediment data to assess potential threats posed by chemicals in RSA-147/148/149 groundwater to populations of ecological receptors.



#### **4.7.1 Subarea 1, Indian Creek**

The Indian Creek Subarea lies within the western and central portions of RSA-149. It is fed primarily by surface water runoff and a number of perennial springs. The northern portion of Indian Creek receives significant groundwater input from perennial springs located within the RSA-150 groundwater unit.

A total of 24 surface water sample results are available from 19 springs and 1 stream in this subarea. An additional six samples were collected from downstream locations. Table 4-1 lists sample locations within each of the three surface water subareas.

#### **4.7.2 Subarea 2, Huntsville Spring Branch**

The Huntsville Spring Branch Subarea encompasses 2,475 acres of riverine and wetland habitat in the southern portions of RSA-147, RSA-148, and RSA-149. Huntsville Spring Branch originates at Big Spring, located north of RSA in downtown Huntsville while the headwaters of McDonald Creek extend to the north of RSA.

Thirty-one surface water samples were collected from 26 springs within the Huntsville Spring Branch Subarea (Table 4-1). An additional 19 samples are available from downstream locations.

#### **4.7.3 Subarea 3, RSA-122 Stream**

The RSA-122 Stream Subarea is located along the eastern border of RSA-147. The perennial stream within the RSA-122 subarea flows north to south and receives surface runoff from the surrounding areas and groundwater discharge from several perennial springs. This perennial stream flows southward to its confluence with Huntsville Spring Branch within the Huntsville Spring Branch Subarea.

Four springs and one stream were sampled within the RSA-122 subarea. Two downstream samples were also collected from one spring location, for a total of six surface water samples within this subarea.

#### **4.8 Soil Vapor**

Five soil vapor samples were collected near areas of elevated VOC concentrations in groundwater. One sample was collected from a large paved area near Building 4381 (148-VP001) within RSA-183. Two vapor samples were collected by NASA/MSFC within the MSFC-034 site; MC-VP03-033 and MC-VP03-034 were collected adjacent to Building 4464. Vapor sample 147-VP001 was collected within RSA-117, beneath the paved area south of Building 5540. A vapor sample (148-VP002) was also collected in the northwestern portion of RSA-053. These samples were collected to characterize VOC concentrations in soil gas. These data are used to support the evaluation of potential risks to human health associated with

exposure to indoor air affected by vapor intrusion (Section 7.1.4). Additional soil vapor samples were collected within the NASA/MSFC area; the results for these samples are presented in the MSFC OU-3 RI report (CH2M Hill, 2012a).

#### **4.9 Summary**

The following key points summarize the data evaluation approach applied to the RSA-147/148/149 RFI:

- This RFI characterizes RSA-147/148/149 groundwater by evaluating data from the analysis of environmental samples collected during multiple investigations.
- Based on assignment in the GRIM for the investigation and delineation of groundwater contamination, RSA-147/148/149 data have been recognized as either the responsibility of the groundwater units or of a surface media site. A field has been added to the data sets presented in Appendix F-1 to define responsibility.
- All available groundwater data are provided in Appendix F-1, but this RFI report focuses only on the data that are the responsibility of RSA-147/148/149.
- The number and distribution of samples and associated analytical results are adequate to determine the nature and extent of site-related chemicals in RSA-147/148/149 groundwater.
- Characterization data are representative of current groundwater conditions and of acceptable quality and usability for meeting the RFI objectives.
- Potential threats posed by chemicals in RSA-147/148/149 groundwater to populations of ecological receptors are evaluated based on data from surface water samples collected from three surface water subareas within the RSA-147/148/149 boundary.

## **5.0 Nature and Extent of Contamination**

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The current understanding of the nature and extent of contamination within RSA-147/148/149 is based not only on data collected as part of the groundwater unit investigations, but also on groundwater data collected as part of environmental investigations conducted at the surface media sites that lie within the RSA-147/148/149 boundaries. To date, investigations have been completed, are ongoing, or are planned at 82 surface media sites (Table 1-1). Those surface media site investigations are designed in part to evaluate the potential for sourcing contaminants to groundwater.

As detailed in Chapter 4.0, a database consisting of the most recent, usable samples collected from the groundwater and surface water sampling locations within RSA-147/148/149 are considered representative of current conditions. These data were used to define the specific sampling locations that are the responsibility and focus of this groundwater unit RFI (Section 4.4). Usability criteria are discussed in Section 4.2.2. The groundwater data set includes samples collected from conventional, nested, and multizone monitoring wells as well as springs. The methods employed to collect groundwater samples from the springs ensured these samples are representative of the discharging groundwater prior to mixing with the surface water in the receiving body.

The remainder of this chapter evaluates these data and presents the following:

- Evaluation of current evidence of DNAPL within RSA-147/148/149, including direct (visual indications) and circumstantial (elevated dissolved-phase concentrations near the chemical's solubility) evidence.
- A statistical and geochemical evaluation of metals data in groundwater and surface water to determine what concentrations represent naturally occurring metals or potential site-related contamination.
- Evaluation of dissolved-phase chemicals that exceed their PSVs in locations that lie outside the six groundwater FAs.
- Evaluation of dissolved-phase chemicals that exceed their PSVs in locations within the six groundwater FAs.

### **5.1 Nonaqueous-Phase Liquids**

Certain chemicals found in RSA-147/148/149 groundwater were detected as DNAPLs. Boreholes in potential and known DNAPL source areas were characterized using FLUTE reactive ribbon liner surveys and by screening of drill cuttings using hydrophobic dyes. DNAPL, where present, will act as continuing source material for dissolved-phase concentrations. The

following general rules are used to evaluate the possibility that a DNAPL primary contaminant source is present in groundwater. Where the concentration of a VOC in groundwater is greater than 1 percent of its solubility limit (EPA, 1998), the presence of DNAPL should be suspected. This threshold concentration indicates that a DNAPL mass may be present within the area or in an upgradient location. Where the chemical concentrations are greater than 10 percent of their solubility (Pankow and Cherry, 1996), it is considered likely that DNAPL is present and likely within the immediate proximity of the well. Considering all historical and current analytical results, five VOCs were detected in RSA-147/148/149 groundwater at concentrations exceeding their 1 percent effective solubility concentrations, indicating a suspected presence of DNAPL:

- CT
- CBZ
- Chloroform
- PCE
- TCE.

Under current conditions (considering only the most recent analyses) and excluding data from within MSFC (but including MSFC-034), only three VOCs exceed the 1 percent solubility threshold:

- CT
- CBZ
- TCE.

However, all three of these compounds also exceed 10 percent of their solubility at one or more sampling locations. Although a concentration greater than 10 percent of a compound's solubility does not confirm the presence of DNAPL, it does indicate that source material may be present in the immediate vicinity of those locations. Further evaluation of the potential impacts from concentrations indicative of DNAPL is included in Chapter 5.0.

The FLUTe reactive ribbon liners provide direct evidence of DNAPL in the borehole, and specifically, where in that hole the DNAPL resides. The liners have hydrophobic dye striping which reacts when in contact with chlorinated organic DNAPL to form a visible stain on the liner material. The depth of the staining is measured from ground surface when the liner is retrieved. One caveat with this technology is that liner stains can also be present as a result of DNAPL smearing along the borehole as tooling is deployed and removed from the hole. Nonetheless, the staining does not occur in dissolved groundwater, regardless of concentration, and so is direct evidence of actual DNAPL presence. The results of the FLUTe liner surveys are summarized in Appendix B-3.

TCE, CBZ, or CT were detected at various locations associated with MSFC-034, RSA-053, RSA-102, and RSA-117 concentrations that exceed 10 percent of their solubility, indicating a likelihood that these chemicals occur as DNAPL near those locations. Table 5-1 lists the specific locations where DNAPL is suspected, based on contaminant concentrations in most recent sampling that exceed the 10 percent solubility criteria. These locations are shown on Figures 5-1a (shallow) and 5-1b (deep). A broader halo exceeding 1 percent of the solubility of these compounds reflects the elevated dissolved-phase plume surrounding the DNAPL locations; locations exceeding the 1 percent threshold are also included in Table 5-1. Sites where DNAPL is suspected and/or confirmed through visual observation are discussed below.

**MSFC-034.** Although MSFC-034 site lies within the northeastern portion of NASA MSFC, the Army and MSFC-034 are responsible for groundwater characterization and remediation. Dissolved-phase concentrations of CT with lesser concentrations of TCE were detected in recent sampling within the shallow flow zone; staining on FLUTe reactive ribbon liners (likely CT) was detected within the shallow bedrock during drilling at other locations with MSFC-034 (Appendix B-3). MSFC-034 is considered a primary source for CT in groundwater within RSA-147/148/149, and the occurrence of this compound at multiple downgradient sites confirms the source relationship, further supported by dye tracing from locations within or nearby to MSFC-034.

**RSA-053.** RSA-053 is located in the eastern-central portion of RSA-148. Dissolved-phase concentrations of CBZ at concentrations indicative of DNAPL were detected in historical and more recent sampling. Elevated concentrations were detected in the overburden and shallow bedrock (Table 5-1), all of which are associated with the NDA portion of RSA-053. No reactive ribbon surveys were conducted at this site.

A corrective action was implemented to address residual DNAPL (CB&I, 2015a). The corrective action employed in situ thermal treatment and was successful at reducing levels of CBZ DNAPL in the saturated zone by up to 85 percent. Remaining groundwater contamination attributed to RSA-053 is the responsibility of the RSA-147/148/149 groundwater units and is addressed as FA-4.

**RSA-117.** RSA-117 is the former Olin Manufacturing DDT pesticide manufacturing plant that herein collectively includes several daughter sites. Free product was observed along with elevated organic vapor analyzer/flame ionization detector readings in unsaturated and saturated overburden in a number of locations within the former DDT plant and associated drainage or surface impoundment locations. Extensive dissolved-phase concentrations of CBZ in excess of 10 percent solubility were detected in shallow and deep wells (Table 5-1); reactive ribbon

surveys conducted at several deep borehole locations within RSA-117 indicate significant staining extending to depths of nearly 300 feet bgs in select locations (Appendix B-3). RSA-117, located in the southern part of RSA-147, is considered a primary source for CBZ in groundwater. Groundwater contamination attributed to RSA-117 and its daughter sites remains the responsibility of RSA-117.

**RSA-183.** RSA-183 hosts two of the former lewisite production facilities and is located east of MSFC-034 in the upgradient, northwestern portion of RSA-148. An elevated concentration of CT was detected in one overburden well (E-RS1367) installed adjacent to a former blowdown sump. Initial concentrations exceeded 10 percent of the solubility, but more recently, the concentrations have declined below that threshold but still exceed 1 percent solubility, indicative of a residual dissolved-phase plume. No reactive ribbon surveys were conducted at this site.

The RSA-147/148/149 groundwater units are responsible for defining the lateral and vertical extent of contamination in groundwater at RSA-183, which is addressed as FA-5.

## **5.2 Metals in Groundwater and Surface Water**

Metals are detected in groundwater and surface water at concentrations exceeding their PSVs and BSVs; however, metals also exist as natural constituents, originating from dissolution of minerals from the soil and bedrock through which the media flow. Therefore, metals concentrations in these media are evaluated using statistical and geochemical methods to determine whether a particular metal concentration is naturally occurring or potential site-related contamination. The nature and extent evaluation portrays current conditions and utilizes the most recent analytical result from each location for each parameter. In contrast, and to be consistent with the human health and ecological risk screening evaluations, the site-to-background comparison utilized metals data from all samples defined in Chapter 4.0 as usable, including samples collected as far back as 2007. Consequently, multiple sample results from the same location were included, in addition to the most recent result. In many instances, the site-to-background comparison identified a metal as anomalous in multiple samples from a single sampling location. In other situations, the site-to-background comparison identified an anomalous metal in a sample while a more recent sample showed no anomaly. The discussion below is based on all usable samples; the quantities listed may differ from the statistics provided in Tables 4-2 and 4-3, which only consider results from most recent samples. The text below is a summary of the statistical and geochemical evaluation; the full evaluation is presented in Appendix G.

In presenting the available metals data and results of the site-to-background comparison, all anomalous results perceived as not naturally occurring and exceeding both the BSVs and PSVs

are listed in Table 5-2. Locations of non-naturally occurring metals exceeding both the BSV and PSV are shown on Figures 5-2a and 5-2b for the shallow groundwater and surface water and the deep groundwater, respectively. The locations are indicated with a red symbol and labelled to correspond to Table 5-2.

**Summary of the Site-to-Background Comparison.** A site-to-background comparison was performed for selected elements in unfiltered groundwater samples and unfiltered surface water samples from RSA-147/148/149 (Appendix G). Included in the comparison were elements with concentrations that exceeded both their corresponding BSV and PSV (human health and/or ecological screening criteria). The table below lists the elements that were selected for each medium for the site-to-background comparison, along with the screening criteria that were exceeded by each element.

Groundwater		Surface Water	
Aluminum	HH	Aluminum	Eco, HH
Arsenic	Eco, HH	Arsenic	Eco, HH
Cadmium	HH	Barium	Eco
Chromium	Eco, HH	Cadmium	Eco
Iron	Eco, HH	Chromium	Eco, HH
Lead	Eco, HH	Cobalt	HH
Manganese	Eco, HH	Copper	Eco
Mercury	HH	Iron	Eco, HH
Nickel	HH	Lead	Eco, HH
Selenium	HH	Manganese	Eco, HH
Silver	HH	Nickel	Eco
Zinc	HH	Silver	Eco
		Thallium	HH
		Vanadium	HH
		Zinc	Eco

Eco – Ecological.  
HH – Human health.

The site-to-background comparison consists of two complementary, EPA-recommended statistical tests followed by geochemical evaluation for any element that fails either or both tests. The hot measurement test compares the upper tails of the site and background distributions by comparing the site concentrations to the BSVs provided in Shaw (2003b) (groundwater) and Shaw (2008b) (surface water) and is designed to detect potential localized contamination. The Wilcoxon rank sum (WRS) test compares the two sets of samples to determine if they were drawn from populations with distributions having similar central tendencies and is designed to detect potential pervasive contamination. Metals concentrations can be naturally elevated and thereby fail statistical comparison to background. Geochemical evaluation is therefore performed for elements that fail either or both statistical tests to determine if the site concentrations have a

natural source or are elevated due to site-related contamination. The geochemical evaluation is based on the known elemental associations and geochemical behavior in groundwater and surface water and considers all available analytical data, field observations, site history, and potential geochemical mechanisms. The site-to-background comparison is performed in accordance with the approved methodology (Shaw, 2003b).

**Groundwater.** Aluminum, arsenic, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc were included in the site-to-background comparison for groundwater. For each element, 1 to 79 concentrations exceed their respective BSVs. Aluminum, iron, manganese, and zinc passed the WRS test. The other 8 elements could not be subjected to the WRS test because of the high percentages of nondetects in their site and background data sets.

The 12 elements failed statistical comparison to background and were therefore subjected to geochemical evaluation, as described in Appendix G. Geochemical evaluation indicates that anomalously high concentrations of aluminum, arsenic, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc are present in 12 to 121 groundwater samples each. These samples are listed in Table 6 of Appendix G. For the 904 samples included in the RSA-147/148/149 groundwater data set, the remaining detections of aluminum, arsenic, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc (i.e., those not specified in Table 6 of Appendix G) are most likely natural.

Metals concentrations are considered to be contamination only if the concentration exceeds the PSV and BSV and are identified in the site-to-background evaluation as anomalous. Table 5-2 lists those locations where metals in most recent samples were detected at concentrations exceeding PSVs and BSVs and identified as statistically and geochemically anomalous.

From examination of Table 5-2, the most frequently detected metals that exceed the PSV and BSV and cannot be considered naturally occurring are arsenic (31 locations), mercury (9 locations), iron (54 locations) and manganese (33 locations). Anomalous concentrations of cadmium, chromium, lead, nickel, and selenium occur sporadically (one to five locations, depending on the metal). Arsenic and mercury were associated with the production of lewisite and consequently are indicators of sourcing from these operations (and related disposal sites). Figure 5-2a shows the distribution of arsenic and mercury determined to be anomalous and indicative of contamination in shallow and deep groundwater. Figure 5-2b shows the locations of the sporadic occurrences of the remaining metals listed in Table 5-2 and discussed above.



From Figure 5-2a, it can be seen that the anomalous concentrations of arsenic and mercury are clearly associated with the lewisite production facilities (RSA-122 and RSA-183) and associated operations, including related disposal sites (RSA-056, RSA-057, RSA-054, RSA-126, and RSA-139). The highest concentrations of arsenic occur within RSA-122 and RSA-139, forming a small plume of limited extent. Arsenic is also detected in several wells at RSA-117. All of these locations are shallow groundwater monitoring points. Arsenic in solution in groundwater is typically associated with low pH and reducing conditions. Since the majority of the shallow groundwater is neutral to slightly alkaline (due to the carbonate hydrogeology) and aerobic/oxic, arsenic rapidly precipitates out and the arsenic plumes are localized.

From Figure 5-2b and Table 5-2, the occurrences of cadmium, chromium, lead, nickel and selenium are limited to one or two locations, and no plumes are evident. Elevated iron is present in 25 shallow groundwater samples and is most mainly associated with the disposal sites within RSA-147 and RSA-148 (RSA-010, RSA-053, RSA-054/055, and RSA-060). Manganese is commonly detected in groundwater, and although anomalous concentrations are above the BSV, the concentrations are within the range observed in the background data set. The 14 locations of anomalous manganese are sporadically distributed in RSA-010, RSA-117, RSA-053, RSA-055, and RSA-056, and not as a plume of any extent.

**Surface Water.** Aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, thallium, vanadium, and zinc were included in the site-to-background comparison for surface water. For each element, one to five concentrations exceed their respective BSVs. Aluminum, barium, iron, and manganese passed the WRS test. The other 11 elements could not be subjected to the WRS test because of the high percentages of nondetects in their site and/or background data sets.

The 15 elements failed statistical comparison to background and were therefore subjected to geochemical evaluation, as described in Appendix G. Geochemical evaluation indicates that all detected concentrations of aluminum, barium, cadmium, cobalt, copper, lead, manganese, silver, thallium, and vanadium are most likely natural in the 77 surface water samples that were included in the RSA-147/148/149 data set and analyzed for TAL metals. Anomalously high concentrations of arsenic, chromium, iron, nickel, and zinc are present in one to six samples each (Table 7 in Appendix G). The remaining arsenic, chromium, iron, nickel, and zinc detections (i.e., those not specified in Table 7 of Appendix G) are most likely natural. Locations where anomalous metals were detected at concentrations exceeding both the PSV and BSV in most recent surface water samples, listed in Table 5-2 and shown on Figures 5-2a and 5-2b, are delineated by locations where metals concentrations are considered to represent natural constituents of surface water. All of the arsenic locations in surface water are from sampled

locations at springs RSP-1504, RSP-1506a, and RSP-1510a, which are located along the stream that flows from RSA-122 (the source of the arsenic). Anomalous arsenic concentrations were not observed in the springs themselves.

### **5.3 Dissolved-Phase Contamination**

In the usable RSA-147/148/149 groundwater and surface water data sets that represent current conditions, 73 chemicals and 13 metals have been identified at concentrations that exceed PSVs and, in the case of metals, their BSVs as well (Tables 4-2 and 4-3). Excluding metals, which are subject to site-to-background comparison (Appendix G), the remaining 73 chemicals are considered potential site-related contaminants to groundwater and fall within the following analytical suites:

- VOCs (22 compounds)
- SVOCs (18 compounds)
- Pesticides/PCBs (20 compounds)
- Explosive compounds (13 compounds).

Within the six FAs and outlier locations that are the responsibility of these groundwater units, 31 chemicals and 3 metals have been identified in the usable and most recent data at concentrations that exceed PSVs (for metals, concentrations exceed both the PSVs and BSVs). The 31 chemicals identified in locations considered to be the responsibility of the groundwater units fall into the following analytical suites:

- VOCs (13 compounds)
- SVOCs (5 compounds)
- Pesticides (6 compounds)
- Explosives (11 compounds).

The exceeding contaminants detected in each FA are presented in Table 5-3. The following text presents the nature and extent of contaminants identified in outlier locations and within each of the six groundwater FAs.

### **5.4 Contaminants Outside Groundwater Focus Areas**

A total of 83 monitoring wells and 1 spring that are the responsibility of the groundwater units lie outside the six groundwater FAs (Figures 4-2 and 4-3). Samples were analyzed for VOCs, SVOCs, pesticides/PCBs, explosives, perchlorate, TAL metals, and other general chemistry parameters. In the most recent, usable data set for groundwater unit-responsible locations, only one PSV exceedance was detected in a monitoring location outside the six FAs.

Benzo(a)anthracene was detected above the PSV (0.03 micrograms per liter [ $\mu\text{g/L}$ ]) PSV in one outlier sampling location. The 0.06  $\mu\text{g/L}$  concentration found in the most recent sample from

H62-RS045, located in the southernmost portion of RSA-148, exceeds the PSV. H62-RS045 is located east-southeast of RSA-109 and south-southwest of RSA-061/062. Benzo(a)anthracene was not detected or detected below the PSV in several locations near H62-RS045 (Figure 5-3). There are sampling locations within and adjacent to RSA-061/062 where low-level benzo(a)anthracene exceedances (less than 0.1 µg/L) were identified. Investigations at RSA-061/062 are deferred (Table 1-1) awaiting an interim measure for potential munitions removal. The benzo(a)anthracene exceedance does not represent a contaminant plume and, in fact, is an isolated exceedance bounded by sampling locations that do not exhibit exceedances.

## **5.5 Focus Area 1**

FA-1 encompasses the RSA-057 surface media site (Figure 5-4). FA-1 falls within the RSA-147 groundwater unit, which encompasses several other surface sites in this part of RSA.

### **5.5.1 Site Description and History**

The RSA-057 site is approximately 8 acres in size and located in the east-central part of RSA with Patton Road to the east, Viper Road to the west, Martin Road to the north, and Mills Road to the south (Figure 5-4). Prior to their closure and removal, RSA-057 was the site of two sludge ponds built to treat and contain liquid wastes from the lewisite production process. The relatively level site is partially wooded with pine trees and thick briars in the eastern half of the site. Remedial action completed in 2009 included surface and subsurface soil removal that cleared the western half of the site (Shaw, 2013c). There are no permanent surface water drainage features and no aquatic habitats within the boundaries of RSA-057, although a shallow storm water ditch is present in the northern portion of the site. During heavy storm events, surface runoff accumulates in the ditch and flows northeast, eventually discharging to a perennial stream northeast of RSA-057 (Figure 5-4).

**Investigative History.** Environmental investigations began in 1987 with the investigation of OU-6 sites, which included sampling within the boundary of RSA-057. Specific investigations at RSA-057 included a 1987 confirmation study completed by P.E. LaMoreaux & Associates, Inc. (PELA), followed in 1989 by a VSI performed by Geraghty & Miller, Inc. (G&M). Environmental Science and Engineering, Inc. (ESE) performed a site characterization study in 1994. RI activities began in 1996 when Rust Environmental & Infrastructure, Inc. conducted the Phase I RI. Shaw continued supplemental RI activities in 1998 and began the Phase II RI in 2002. Analytical results from the most recent RSA-057 and FA-1 groundwater sampling activities are presented in Appendix F-1.

**Corrective Measures.** Corrective measures activities were performed at RSA-057 in 2008 to remove soils contaminated with arsenic and mercury from historical operations at the site. From

March through October 2008, a total of 22,291 tons of arsenic- and mercury-contaminated soil were excavated and disposed as nonhazardous special waste (Shaw, 2009b). Soil excavation depths ranged from 1 foot to over 12 feet. A total of 95 confirmation samples were collected following excavation activities. Based on the results of the confirmation samples, the remedial action completion report (Shaw, 2009b) concluded that all soil containing elevated arsenic and mercury concentrations had been removed at RSA-057.

As part of the site's corrective measures implementation, a baseline groundwater sampling event was conducted in December 2008 and January 2009 (Shaw, 2013a). These data form the basis for comparison of subsequent sampling events. Four post-remediation sampling events were conducted: two short-term groundwater sampling events in July 2010 and July 2011 and two additional groundwater sampling events in July 2012 and August 2013 that were in accordance with the requirements contained in the Redstone Arsenal Hazardous Waste Facility Permit.

Arsenic and mercury were not detected in the July 2012 groundwater samples. Low concentrations of arsenic and mercury were found in one monitoring well (F57-RS1389) during the 2013 monitoring event. Arsenic was estimated at 4.33 µg/L, below both its PSV and BSV. However, mercury was detected at a concentration of 1.15 µg/L, exceeding its BSV but less than the PSV. The concentrations of arsenic and mercury have either decreased or remained within the same order of magnitude between the 2008/2009 baseline sampling and the 2013 sampling, indicating that the remedial action activities did not mobilize these site-related contaminants. The results of the baseline sampling conducted in 2008 and 2009 followed by four years of post-remediation sampling from 2010 through 2013 support the conclusion that groundwater was not impacted by the remedial activities and the removal of contaminated soil has eliminated the potential source to groundwater.

### **5.5.2 Hydrogeology**

Groundwater occurs in both the unconsolidated overburden and bedrock at FA-1, primarily as a single, unconfined water table aquifer. Groundwater was also discovered at RSA-057 in shallow, discontinuous lenses above the true water table aquifer. This perched water is the result of infiltration and seasonal fluctuations in overburden groundwater levels trapped in more permeable sand/silt lenses within the less permeable clay overburden. These lenses are discontinuous across the site and typically saturated following periods of seasonally high groundwater elevations. Figure 5-5 presents the estimated extent of perched groundwater. Based on the most recent groundwater elevation data collected from monitoring wells in the area that monitor the true water table, the overall direction of groundwater flow at FA-1 is to the east-southeast (Figure 5-5) with localized flow components to the east-northeast. Historical water level statistics for each location are provided in Appendix D.

### **5.5.3 Nature and Extent of Groundwater Contamination**

The current understanding of the nature and extent of contamination within FA-1 is based not only on data collected as part of the RSA-147/148/149 groundwater unit investigations but also on groundwater data collected as part of environmental investigations conducted at surface media site RSA-057 and sites that lie adjacent to the FA-1 boundary. Surface media site investigations were designed in part to determine contaminant sources and evaluate their potential for impacting groundwater. The nature and extent evaluation is based on the results of the most recent samples collected from seven overburden and one interface wells within the boundary of FA-1. Table 5-4 provides basic statistical information for the FA-1 analytical data, including number of most recent, usable samples collected; number of concentrations that exceed screening criteria; and the minimum detected concentrations and maximum detected concentrations (MDC). Several additional overburden, interface, and bedrock monitoring wells located outside the FA-1 boundary were used to confirm delineation of contamination. FA-1 samples were analyzed for VOCs, SVOCs, pesticides/PCBs, explosives, TAL metals, and other general chemistry parameters.

No PSVs were exceeded in the most recent, usable samples analyzed for SVOCs, pesticides/PCBs, explosives, and metals. In samples analyzed for VOCs, only TCE was detected in FA-1 groundwater at concentrations that exceed a PSV. The following paragraphs describe the extent of TCE contamination in groundwater at FA-1.

TCE is present in 12 of the 21 samples collected in and around FA-1 at concentrations ranging from 0.53 J to 32 µg/L. TCE's 5 µg/L PSV was exceeded in samples collected from three monitoring wells within the shallow zone (F57-RS731, F56-RS049, and F122E-RS951). The distribution of TCE in RSA-057 groundwater samples is shown on Figure 5-6. The highest TCE concentration (32 µg/L) was detected in the sample from well F57-RS731. It is likely that historical disposal of lewisite production wastes in the two ponds at the site is the source for the localized TCE plume at RSA-057.

The TCE groundwater plume encompasses a majority of RSA-057 and continues south for approximately 825 feet, west for approximately 525 feet, and north for approximately 500 feet. The plume is laterally bound to the north by monitoring well Z-RS1230S. The eastern boundary is defined by 294-RS2494, F57-RS140, F57-RS1390, and F57-RS141. Monitoring wells F57-RS141 and 290-RS2304 define the southern boundary of the plume. The plume is bound to the west by 290-RS2404, F127-RS1464, F57-RS732, F57-RS1389, and F126-RS946. Vertical migration of TCE is not occurring at RSA-057, as confirmed by the absence of PSV exceedances in most recent samples from deep flow zone monitoring wells Z-RS1230D to the north, Z-RS1236D to the south, and F122-RS513 to the west. An analytical summary of data from deep

wells in this area is provided in Table 5-5; well locations are shown on Figure 5-7. Vertical delineation is also confirmed to the east by the lack of PSV exceedances in the most recent sample from 145-RS1678, a downgradient bedrock monitoring well screened to a depth of 48 feet bgs (Figure 5-6).

#### 5.5.4 Summary and Conclusions

TCE was identified in groundwater at concentrations exceeding the PSV in 12 of the 21 sampling locations evaluated for FA-1. Concentrations ranged from 0.53 J to 32 µg/L, with the highest concentration detected at F57-RS731. The source for TCE contamination at RSA-057 is believed to be historical disposal of lewisite production wastes in ponds at the site.

The level of investigations conducted at RSA-057 (FA-1) is considered sufficient to fully define the nature and extent of contamination in groundwater. TCE is the only contaminant at FA-1, and the nature and extent of TCE at FA-1 is adequately bounded to support remedial decision making. Corrective measures for groundwater will be conducted as part of the RSA-147 groundwater unit study, as summarized below:

			Unit Responsible for Addressing Groundwater COCs	
Focus Area	SWMUs	Relevant Groundwater COCs	Delineation	Remedy
FA-1	RSA-057	TCE	RSA-147	RSA-147

### 5.6 Focus Area 2

FA-2 consists of approximately 44.5 acres of land encompassing the RSA-122 surface media site and includes several sites that lie within and adjacent to the RSA-122 boundary (Figure 5-8). FA-2 falls within the RSA-147 groundwater unit, which encompasses several other surface sites in this part of RSA.

#### 5.6.1 Site Description and History

The following provides a brief history of operations, investigations, and remedial actions conducted at the surface media sites that relate to FA-2.

**Corrective Measures.** Corrective measures were completed at RSA-122 in 2011.

Approximately 8,300 tons of arsenic- and mercury- contaminated soil were excavated from discrete areas across the RSA-122 site. The areas of soil excavation did not include the RSA-056/139 pond areas, which were previously capped. The corrective measures, in conjunction with ongoing LUC implementation, were effective in meeting the objectives specified for

protecting current and future industrial receptors and construction workers from exposure to arsenic and mercury in soil.

#### **5.6.1.1 RSA-122**

RSA-122 occupies 42 acres of land in the east-central portion of RSA and is the former site of lewisite manufacturing operations. The area is located to the west of Patton Road, north of Viper Road, south of Metrology Drive, and east of Jungerman Road and includes an unnamed north-south-trending perennial creek that ultimately discharges to Huntsville Spring Branch (Figure 5-8). Included within the RSA-122 and FA-2 boundaries are several former chemical manufacturing areas, waste disposal ponds associated with these manufacturing operations, and other inactive NFA sites. Active sites are discussed separately below.

RSA-122 includes the following components of lewisite manufacturing, which have now been dismantled (Figure 5-8):

- The adjacent sulfur monochloride and AT manufacturing areas were located in the northwestern portion of the site.
- Former Lewisite Plants 3, 4, 5, and 6 were located in the southwestern and eastern parts of the site.

#### **5.6.1.2 RSA-056 and RSA-139**

RSA-056 and RSA-139, located in close proximity in the northwest portion of RSA-122, were ponds for the disposal of lewisite manufacturing wastes. These sites were shallow, unlined waste disposal ponds, and conditions at these two sites are very similar. The two areas collectively occupy approximately 3 acres. When in use in the early 1940s, the ponds were open, unlined surface impoundments that received arsenic-contaminated industrial waste sludge and liquids from lewisite manufacturing facilities at RSA-122.

The lewisite manufacturing plants were dismantled and demolished sometime around 1960. Select plant debris was flashed and salvaged, and the remaining plant debris was bulldozed into the RSA-056 and RSA-139 ponds. The ponds remained partially open after the plant sites were razed, but were filled with soil and asphalt rubble in 1972. A 2.5-foot-thick protective soil cover (clay and topsoil) was placed over the ponds pursuant to a 1995 interim remedial action and a 2000/2001 time-critical removal action (TCRA) conducted at the site (Shaw, 2009c).

### **5.6.1.3 Inactive Surface Media Sites**

In addition to the RSA-122 site and the active sites within its boundary, the following NFA sites are located within the boundary of FA-2:

- RSA-033 – Plating Room Floor Drains, Building 5432. Building 5432 was used as an electroplating shop beginning in 1974; the site consists of floor drains located inside the building. No releases were observed and the areas appeared clean during the RCRA facility assessment (ADEM, 2008).
- RSA-044 – Underground Used Oil Storage Tank, Building 5435B. Located immediately south of the former AT plant area, this small site consists of a former 500-gallon underground waste oil storage tank that was located on the north side of Building 5435. At one time, the tank received hydraulic waste oil from calibration equipment used within Building 5435. No evidence of a release was noted during the RCRA facility assessment (ADEM, 2008)
- RSA-127 – Photo Lab Process Wastewater Sump, Building 5451. This site was a concrete sump located outside Building 5451 in the southeastern portion of RSA-122 and served as a photographic processing laboratory. A release assessment conducted in 2001 confirmed the presence of metals in soils above RSA background levels. A remedial action which included soil removal was implemented in 2002. An RFI to characterize the nature and extent of releases at RSA-127 was implemented in January 2004. The RFI indicated an additional area of silver contamination in soil along the drainage ditch located just south of the site that received runoff from the site. Additional soil removal was conducted to address the elevated silver concentrations in soil associated with the ditch. NFA for surface media was granted, with groundwater to be managed as part of RSA-147.

**Investigative History.** Investigations at sites within FA-2 began 1978 when a geohydrologic characterization survey was completed by TESTING, Inc., which included the installation and sampling of four shallow zone monitoring wells around the RSA-056 and RSA-139 capped waste disposal ponds. In 1988, PELA collected subsurface soil and groundwater samples, which were followed in 1989 by a VSI performed by G&M. ESE performed a site characterization study in 1994, and the USACE Huntsville Division completed an interim remedial design for RSA-056 and RSA-139. In 1997, a Phase I RI was completed by IT. IT initiated supplemental RI and TCRA activities in 2000. In 2001, additional activities in support of the TCRA were completed by IT. Phase II RI activities were initiated in 2004 and completed in 2005 by Shaw.

The Phase II groundwater investigation at RSA-122 included the installation and sampling of 24 additional groundwater monitoring wells and 53 shallow piezometers to further define the nature of contamination in groundwater at RSA-122 and determine if contaminants in soils are leaching to groundwater. Groundwater was investigated through the installation of 11 shallow overburden wells to monitor perched groundwater identified at the site. Eleven shallow



overburden/overburden well pairs were installed to determine if contaminants were leaching from soil to perched water and if contaminants in perched water were making their way to the water table aquifer; two additional shallow overburden wells were paired with existing overburden wells.

To further study perched groundwater in the Phase II RI, piezometers were installed adjacent to 53 soil borings where a shallow saturated perched water zone was identified. These saturated lenses of clayey silt and/or clayey sand were approximately 0.5 to 3 feet thick and were encountered at depths ranging from 3.5 to about 8 feet bgs in the northwestern part of RSA-122 and from 6 to 12 feet bgs in the southern and eastern parts of RSA-122.

### **5.6.2 Groundwater Hydrogeology**

Groundwater occurs in both the unconsolidated overburden and bedrock at FA-2, primarily as a single, unconfined water table aquifer. Groundwater also occurs as perched water within FA-2, and there is evidence to suggest that perched water is being continuously recharged, possibly by leaking water lines. Although the underlying water table elevation is observed to decline seasonally with the onset of the dry season and increased evapotranspiration, the perched water levels remain fairly constant, suggesting a perennial recharge source.

The most recent groundwater elevation measurements obtained from true water table monitoring wells within FA-2 were used to create the potentiometric surface map provided as Figure 5-9. The current potentiometric surface indicates local groundwater flow is predominantly south, with east-southeast and southwest components.

Historically, water levels indicate a shallow overburden (perched) groundwater zone covering much of the FA-2 area. The extent of this perched zone is graphically represented on Figure 5-9, as identified by observations made during drilling operations in 2004 and 2005.

### **5.6.3 Nature and Extent of Groundwater Contamination**

The current understanding of the nature and extent of contamination within FA-2 is based not only on data collected as part of the RSA-147/148/149 groundwater unit investigations but also on groundwater data collected as part of environmental investigations conducted at surface media sites within FA-2 and sites that lie adjacent to its boundary. Analytical data from most recent groundwater samples from the 62 shallow zone monitoring wells and 1 deep zone well installed within FA-2 were evaluated to determine the nature and extent of contamination. Table 5-6 provides basic statistical information for the FA-2 analytical data, including number of most recent, usable samples collected; number of concentrations that exceed screening criteria; and the minimum detected concentrations and MDCs. Additional monitoring well, hydropunch,

and piezometer locations in the vicinity of FA-2 were used, as needed, to help define the lateral and vertical extent of contamination.

FA-2 groundwater samples were analyzed for VOCs, SVOCs, explosives, TAL metals, and other general chemistry parameters. Contaminants of interest within FA-2 include the following:

- VOCs (four compounds),
- SVOCs (five compounds)
- Metals (two elements).

All site-related chemicals that exceed their PSVs are considered contaminants and evaluated in the following sections. The distribution of these contaminants in FA-2 overburden groundwater is shown on Figures 5-10 through 5-13. No contaminant concentrations exceeded PSVs in the most recent sample from the FA-2 deep groundwater monitoring well (F122-RS513). The following paragraphs present the extent of contamination identified in the shallow zone.

#### **5.6.3.1 Volatile Organic Compounds in Groundwater**

Four VOCs were detected at concentrations above their PSVs in shallow groundwater at FA-2; no PSV exceedances were detected in the deep flow zone (Table 5-6). The nature and extent of these compounds is presented in the following text, in decreasing order of detection frequency above their PSVs.

**TCE.** TCE was released to the environment as part of the lewisite production process and the disposal of wastes at disposal ponds within RSA-056 and RSA-139. TCE is present in 32 of the 62 shallow zone samples analyzed for it, at concentrations ranging from 0.24 J to 220 µg/L (Table 5-6). Of the 32 detections, TCE concentrations exceed the 5 µg/L PSV in 7 sampling locations (Figure 5-10). TCE is the most frequently detected contaminant at FA-2; however, TCE was not detected in the FA-2 deep flow zone sample.

TCE concentrations exceeding the 5 µg/L PSV are scattered throughout FA-2 with no definitive pattern. The highest TCE concentration (220 µg/L) is located in the southwestern portion of RSA-122, in the sample from F122-RS631 (Figure 5-10). However, F122-RS631 is surrounded by sampling locations where TCE did not exceed the PSV. A total of 39 well and piezometer locations within FA-2 had TCE detections that did not exceed the PSV. As shown on Figure 5-10, the extent of TCE exceedances in groundwater at FA-2 is fully defined laterally by the following wells:

- South (downgradient) - 225-RS1900, 225-RS1902, 030-RS2796, F122-RS050, F56-RS051, F127-RS1467, and others

- East (downgradient and cross-gradient) - F127-RS1464, F57-RS732, and others
- North (upgradient) - F56-RS518, F122N-RS1265, F122N-RS1263, F122NW-RS1257, F139-RS523, and others
- West (cross-gradient and downgradient) - F139-RS915, F122-RS512, 225-RS2043, and others.

Vertical migration of TCE is not occurring at FA-2, as confirmed by the absence of PSV exceedances in most recent samples from deep flow zone monitoring wells F122-RS513 within FA-2, F54-RS300 and Z-RS1230D to the north, Z-RS1236D to the south, and F55-RS1063 to the west. An analytical summary of data from deep wells in this area is provided in Table 5-5; well locations are shown on Figure 5-7. Vertical delineation is also confirmed to the east by the lack of PSV exceedances in the most recent sample from 145-RS1678, a downgradient bedrock monitoring well screened to a depth of 48 feet bgs (Figure 5-10).

**PCE.** PCE is present in 11 of the 62 shallow zone samples analyzed for it (Table 5-6). Concentrations in shallow groundwater range from 0.4 J to 8.6 µg/L. Of the 11 detections, PCE was detected only once at a concentration exceeding the 5 µg/L PSV. A concentration of 8.6 µg/L was detected in monitoring well F122NW-RS1255, located in the northwestern portion of FA-2 (Figure 5-10). This well is surrounded by sampling locations where PCE was not detected or was detected below the PSV, including F139-RS522 and F139-RS523 to the north (upgradient), F122NW-RS1257 to the east (cross gradient), F139-RS1027 to the south (downgradient), and F122NW-RS1248 to the west (downgradient). PCE was not detected in deep flow zone monitoring wells at and surrounding FA-2 (Table 5-5; Figure 5-7).

Historical disposal activities have likely been a source of release for the PCE detected in groundwater at FA-2; however, the extent of the single PSV exceedance of this compound is delineated both laterally and vertically.

**1,1,2,2-TeCA.** 1,1,2,2-TeCA is present in only 1 of the 62 shallow zone samples analyzed for it (Table 5-6). A concentration of 0.55 µg/L was detected in the sample from F122NW-RS1255, exceeding the PSV of 0.076 µg/L. However, the F122NW-RS1255 location in the northwestern part of FA-2 (Figure 5-10) is surrounded by locations where 1,1,2,2-TeCA was not detected, including F139-RS522 and F139-RS523 to the north (upgradient), F122NW-RS1257 to the east (cross gradient), F139-RS1027 to the south (downgradient), and F122NW-RS1248 to the west (downgradient). 1,1,2,2-TeCA was not detected in the deep flow zone monitoring well at FA-2 (Table 5-5; Figure 5-7). The extent of the single exceedance of this compound is considered delineated both laterally and vertically.

**Bromomethane.** Bromomethane is also present at a concentration above the 0.75 µg/L PSV in the most recent sample from one location within FA-2 (Table 5-6). A concentration of 5 J µg/L was detected in the sample from F122NW-RS1261 (Figure 5-10) and exceeds the PSV. However, the F122NW-RS1261 location is surrounded by locations where bromomethane was not detected, including F139-RS522 and F139-RS523 to the north (upgradient), F122NW-RS1257 to the east (cross gradient), F139-RS1027 to the south (downgradient), and F122NW-RS1248 to the west (downgradient). Bromomethane was not detected in the deep flow zone monitoring well at FA-2 (Table 5-5; Figure 5-7). The extent of the single exceedance of this compound is delineated laterally and vertically.

#### **5.6.3.2 Semivolatile Organic Compounds in Groundwater**

Five SVOCs were detected at concentrations above their respective PSVs in one or more of the usable, most recent FA-2 groundwater samples (Table 5-6; Figure 5-11). The nature and extent of these compounds is presented in the following text, in decreasing order of detection frequency above their PSVs. Only the PSV exceedances within FA-2 are discussed below. Additional PSV exceedances shown on Figure 5-11 are the responsibility of surface media sites outside of FA-2.

**Bis(2-ethylhexyl)phthalate.** Bis(2-ethylhexyl)phthalate was the most frequently detected SVOC in exceedance of a PSV at FA-2 with concentrations ranging from 0.46 J to 44 µg/L. Bis(2-ethylhexyl)phthalate was detected above the PSV in six wells at FA-2 (Figure 5-11). Normal operation of this industrialized site is the source of bis(2-ethylhexyl)phthalate and other SVOCs. Four of the six sample locations with exceedances are in or immediately adjacent to the perched groundwater zone. The extent of their presence in the perched groundwater is defined by the extent of the perched groundwater itself (Figure 5-11). Further, the perched groundwater is acting as the source for PSV exceedances found in the overburden wells that monitor the water table.

**Benzo(a)anthracene.** Benzo(a)anthracene was detected in 3 of the 34 most recent samples with all three concentrations exceeding the PSV (Figure 5-11). Concentrations range from 0.1 J to 0.27 µg/L. Two (F127-RS1323 and F56-RS630) of the three exceedances are located within the perched groundwater zone and the third (F127-RS1465) is located adjacent to and downgradient of the perched groundwater. The extent of benzo(a)anthracene in perched groundwater is ultimately defined by the extent of the perched groundwater itself (Figure 5-11). Further, the perched groundwater is acting as the source for PSV exceedances found in the overburden well monitoring the water table.

**Dibenz(a,h)anthracene.** Dibenz(a,h)anthracene was detected in two samples with concentrations of 0.14 J and 0.23 µg/L (Figure 5-11). Both concentrations exceed the PSV. The highest concentration was detected in the sample from F56-RS630 which monitors the perched groundwater zone. The other dibenz(a,h)anthracene exceedance was detected in a sample collected from monitoring well F127-RS1465, located adjacent to and downgradient of the perched groundwater.

**Benzo(a)pyrene.** Benzo(a)pyrene was detected in two samples at concentrations of 0.17 J and 0.28 µg/L (Figure 5-11). Only the highest concentration exceeds the PSV, which was detected in monitoring well F56-RS630, which monitors perched groundwater.

**Naphthalene.** Naphthalene was detected once, but exceeded the PSV in monitoring well F122NW-RS1258. This monitoring well monitors the perched groundwater (Figure 5-11).

As discussed above, years of normal operation of this industrialized area has sourced the SVOCs detected at concentrations exceeding their PSVs. For each of the five SVOCs within FA-2 that exceed their PSV, the highest concentrations were detected in the perched groundwater. The remaining PSV exceedances are immediately adjacent to the perched groundwater zone (Figure 5-11). The extent of the SVOC presence in perched groundwater is defined by the extent of the perched groundwater itself (Figure 5-11). The perched groundwater is acting as the source for PSV exceedances found in the overburden wells that monitor the water table. The lateral extent of SVOCs in the water table aquifer at FA-2 are delineated by surrounding locations where SVOCs were not detected or detected below PSVs (Figure 5-11), including F139-RS522, F126-RS945, and F126-RS1054 to the north; F122N-RS1265, F122E-RS1266, and F127-RS1464 to the east (downgradient); F127-RS1467 and F122S-RS1273 to the south (downgradient); and F122S-RS1275, F139-RS1027, and F122NW-RS1261 to the west (downgradient). No PSV exceedances were detected in the deep flow zone at FA-2 (Table 5-5; Figure 5-7).

#### **5.6.3.3 Metals**

Metals are detected in FA-2 groundwater at concentrations exceeding their PSVs and BSVs; however, as explained in Section 5.2, metals also exist as natural constituents of soil and groundwater. Therefore, metals concentrations in these samples were evaluated using statistical and geochemical methods to determine whether a particular metal concentration is naturally occurring or is potential site-related contamination. At FA-2, there are specific arsenic and manganese concentrations that exceed both their BSVs and PSVs that have been determined through this evaluation to be contamination.

Arsenic was detected in nine monitoring wells at concentrations that exceed both the PSV and BSV and were determined through the site-to-background analysis to be potential contamination (Table 5-2; Figure 5-12). The arsenic concentrations from these nine locations range from 14 to 2,800 µg/L and all nine monitor the perched groundwater zone or the overburden directly below perched groundwater. The maximum arsenic concentration (F122NW-RS1259) was detected in a former drainage feature on the south side of the RSA-139 waste disposal pond. A total of 24 additional sample locations within FA-2 had detections of arsenic but did not exceed screening criteria.

Arsenic contamination in groundwater at FA-2 is the result of releases of arsenic used in the manufacturing of lewisite, an arsenic-based chemical warfare agent, and the disposal of AT wastes in ponds at the RSA-122 site. The extent of arsenic contamination is defined by the extent of perched groundwater (Figure 5-12) and in the overburden by F139-RS522 and F139-RS523 to the north; F122NW-RS1257, F122E-RS1266, and F122E-RS1268 to the east; F122S-RS1273 and F122S-RS1275 to the south; and F139-RS1027 and F139-RS915 to the west. Arsenic did not exceed screening criteria in deep groundwater (Table 5-5; Figure 5-7).

Manganese was detected above the PSV and BSV in two FA-2 monitoring wells at concentrations of 3,400 µg/L in F56-RS630 and 4,500 µg/L in F122NW-RS1258. Of these two concentrations, only the 3,400 µg/L in F56-RS630 was determined through the site-to-background evaluation to be potential contamination (Table 5-2; Figure 5-13). Monitoring well F56-RS630 monitors the perched groundwater zone. An additional 44 monitoring wells within FA-2 had detections of manganese that did not exceed screening criteria. A majority of these locations are also located within the perched groundwater zone. The extent of the anomalous manganese concentration in perched water is delineated by the extent of the perched groundwater (Figure 5-13).

#### **5.6.4 Summary and Conclusions**

Available analytical results indicate historic lewisite manufacturing activities have led to localized contamination of the groundwater by VOCs, SVOCs, arsenic, and manganese. Suspected release points for these contaminants include facilities associated with lewisite manufacturing and waste disposal. These include collecting pits, sumps, trenches, the underground waste transfer lines between waste collection points, the underground chemical transfer lines (used to transfer raw and finished materials throughout the plants), the industrial sewer lines serving the area and their outfalls, and the RSA-056 and RSA-139 waste disposal ponds. The downward movement of contaminants is impeded or captured by widespread but discontinuous lenses of perched groundwater, but perched groundwater also acts as a secondary source to the underlying water table aquifer.

TCE is the most common VOC detected in groundwater at FA-2. TCE is present in groundwater through its use as a solvent during the lewisite manufacturing process and its presence in the waste stream. No mappable plume pattern is evident that would suggest site soils serve as a continuing source for groundwater contamination.

Bis(2-ethylhexyl)phthalate was the most frequently detected SVOC contaminant (six sample locations) in exceedance of the PSV at FA-2. Four of the six sample locations with bis(2-ethylhexyl)phthalate exceedances are in or immediately adjacent to the FA-2 perched groundwater zone and the remaining two are located within 90 feet of the perched groundwater. PAH detections are sporadic across the site, and none are known to be relatable to processes or operations within RSA-122.

Localized arsenic contamination has been identified in shallow overburden (perched zone) monitoring wells associated with the former AT plant, near the capped waste disposal ponds (RSA-056 and RSA-139) and former Lewisite Plants 3 and 4. Former trenches, pits, sumps, and the waste disposal ponds are the likely sources of arsenic in overburden groundwater. Manganese detections at FA-2 are more numerous than arsenic, but the only concentration exceeding both the PSV and BSV and determined through the site-to-background comparison to be potential contamination was detected in perched groundwater. No PSV exceedances were detected in the deep flow zone at FA-2, confirming that vertical extent of contamination is confined to the shallow flow zone (Table 5-5; Figure 5-7).

With respect to site characterization, the nature and extent adequately addresses all likely process-related features and identified release points (i.e., waste collecting pits, trenches, industrial piping and sewer lines, etc.), yielding a data set that is sufficient to support remedial decision making. Relevant COCs for FA-2 and the Army's plan for addressing these COCs are summarized below:

Focus Area	SWMUs	Relevant Groundwater COCs/COACs		Unit or Site Responsible for Addressing Groundwater COCs	
				Delineation	Remedy
2	RSA-122 RSA-056 RSA-139	TCE PCE 1,1,2,2-TeCA Bromomethane Bis(2-ethylhexyl)phthalate Benzo(a)anthracene	Dibenz(a,h)anthracene Benzo(a)pyrene Naphthalene Arsenic Manganese	RSA-147	RSA-147

### 5.7 Focus Area 3

FA-3 is located in the central portion of RSA and encompasses RSA-075 and the southern portion of RSA-279, both NFA surface media sites. Small portions of RSA-059 and RSA-117

are included in the southern portion of FA-3 (Figure 5-14). FA-3 falls within the RSA-147 groundwater unit, which also encompasses other surface sites within the area.

#### **5.7.1 Site Description and History**

Former Building 5413 was located off Mills Road, just west of Building 5410 and north of Building 5415. Former Building 5413 (formerly 713) was constructed in 1943 and used originally as a control analytical laboratory under the office of surveillance and Army Inspector of Ordnance. Floor plans of Building 5413, dated 1954, indicated utilization of approximately 5,700 square feet consisting of laboratory space (metal parts, gage, and chemical), reproduction, and administration. Types and volumes of chemicals used were not determined. Discharge to the industrial sewer from Building 5413 was noted on engineering drawings to be from two legs of 8-inch vitrified clay piping running south to connections south of Mills Road (7120-565A, SE-4, dated 1942). The type and volume of discharge to the industrial sewer is unknown. Building 5413 was part of the Inspection Division, which consisted of two branches: the Material Rocket and Missile Branch and the Equipment and Inspection Services Branch. The building was damaged by fire in 1958 and activities were temporarily housed in Building 5664. Building 5413 activities were resumed in January 1959, but by May 1959 all activities were relocated to Building 5451 as a result of the space limitations in Building 5413. Building 5413 was removed sometime between 1959 and 1964.

#### **5.7.2 Hydrogeology**

Groundwater occurs as an unconfined water table aquifer within the overburden and upper bedrock units, with groundwater typically first encountered in the overburden. Groundwater within the overburden and shallow bedrock is hydraulically interconnected. Figure 5-15 presents the potentiometric surface for the shallow unconfined water table aquifer based on synoptic measurements collected in February 2017. Historical water level statistics for each location are provided in Appendix D. Based on water level measurements taken in February 2017, groundwater flow is predominantly to the east-northeast.

#### **5.7.3 Nature and Extent of Contamination**

The current understanding of the nature and extent of contamination within FA-3 of the RSA-147/148/149 groundwater unit is based not only on data collected as part of the RSA-147/148/149 groundwater unit investigations but also on groundwater data collected as part of environmental investigations conducted at surface media site FA-3. Surface media site investigations are designed in part to evaluate the potential for sourcing contaminants to groundwater.



A database consisting of the most recent, usable samples collected from groundwater sampling locations within and in close proximity to FA-3 are considered representative of current conditions and used to evaluate the nature and extent of contamination. Usability criteria are discussed in Section 4.2.2. The groundwater data set includes samples collected from conventional, nested, and multizone monitoring wells. This section describes the nature and extent of contamination in groundwater at FA-3 within the RSA-147/148/149 groundwater unit.

In the usable FA-3 groundwater data sets that represent current conditions, three VOCs have been identified at concentrations that exceed PSVs (Table 5-7). The three VOCs are considered potential site-related contaminants to groundwater. The nature and extent of the contaminants detected in groundwater at concentrations above their PSVs was evaluated using all available information on groundwater flow regimes to determine lateral and vertical extents of contamination within both the shallow and deep groundwater flow zones.

**TCE.** TCE is present in one of the five FA-3 samples analyzed for it (Table 5-7). TCE was detected in a sample at 147-RS1972 at a concentration of 8.53 µg/L, exceeding the PSV (5 µg/L). The exceedance was a single isolated detection. TCE was either not detected or was below the PSV in downgradient wells within RSA-F, FF-RS1447, FF-RS1449, F-RS2475, and F-RS2476. The single detection is bounded in all directions by wells in which TCE was either not detected or was detected below the PSV: F55-RS1068 to the north; FF-RS1449 and F-RS2475 to the northeast; F59-RS220; F117-RS387, and F117-RS601 to the east and southeast; F117-RS637 and 147-RS2247 to the south and southwest, respectively; and piezometer 1470 2D01-HP02 to the west (Figure 5-16). TCE is the most ubiquitous groundwater contaminant in the RSA-147/148/149 groundwater unit. The single occurrence of TCE in FA-3 is downgradient of a TCE plume to the west-southwest.

**1,1,2,2-TeCA.** 1,1,2,2-TeCA is often detected as a collocated contaminant with TCE. 1,1,2,2-TeCA was detected in the same overburden well 147-RS1972 as TCE at a concentration of 5.61 µg/L, exceeding the PSV (0.076 µg/L). Similar to TCE, the exceedance was a single isolated detection. 1,1,2,2-TeCA was not detected in downgradient wells within RSA-F (Figure 5-17).

**CT.** CT was detected in one of the six samples analyzed for it (Table 5-7). The single CT detection at a concentration of 27.6 µg/L exceed the PSV (5 µg/L). CT was not detected in downgradient wells within RSA-F (Figure 5-18).

There are currently no deep bedrock wells within FA-3. However, deep bedrock wells in areas surrounding FA-3 are useful to define the vertical extent of contamination detected in the shallow flow zone at FA-3. In the deep wells shown on Figure 5-19, only TCE was detected at a

concentration exceeding its PSV. TCE was detected at a concentration of 81 µg/L in well Z-RS1232D, located well south of FA-4 and associated with surface media site RSA-117 (Figure 5-19; Table 5-8). Neither 1,1,2,2-TeCA nor CT were detected in Z-RS1232D. Contamination associated with Z-RS1232D is the result of historical operations at and the responsibility of RSA-117. From the analytical summary information on Table 5-8, TCE and other contaminants do not exceed their PSV in other deep wells south of FA-3 (Figure 5-19), confirming the vertical delineation of FA-3 contaminants.

**Summary and Conclusions.** Three VOCs have been identified at FA-3 at concentrations above PSVs; all were single detections in monitoring well 147-RS1972. The single detection is bounded in all directions by wells in which VOCs were either not detected or were detected below the PSVs. Because the VOC concentrations are well below their solubility limits, it is unlikely that vertical gradient is an issue of concern in the area. Well 147-RS1972 will be included in the LTM program.

Relevant COCs for FA-3 and the Army's plan for addressing these COCs are summarized below:

Focus Area	SWMUs	Relevant Groundwater COCs/COACs	Unit or Site Responsible for Addressing Groundwater COCs	
			Delineation	Remedy
3	RSA-075 RSA-279	TCE 1,1,2,2-TeCA CT	RSA-147	RSA-147

## 5.8 Focus Area 4

FA-4 is located in the central portion of RSA and encompasses portions of three surface media sites: the western portion of RSA-053, the southernmost portion of RSA-183, and the eastern portion of RSA-010 (Figure 5-20). FA-4 falls within the RSA-148 groundwater unit, which also encompasses other surface sites within the area.

### 5.8.1 Site Descriptions and History

Sections 5.8.1.1 and 5.8.1.2 provide a brief history of operations, investigations, and remedial actions conducted at the surface media sites that relate to FA-4.

#### 5.8.1.1 RSA-053

The RSA-053 is a closed sanitary and industrial waste landfill occupying approximately 50 acres in the central portion of RSA (Figure 5-20). The site is located directly east of RSA-010 (Closed Sanitary Landfill), north of Huntsville Spring Branch and adjacent to Wheeler National Wildlife Refuge. The former Olin Chemical plant, a DDT manufacturing facility, was located approximately one-half mile east of RSA-053. The site consists of a series of landfill trenches

and waste oil pits used from the 1950s through 1973 for the disposal of household, administrative, and industrial wastes, as shown on Figure 5-21.

The RSA-053 landfill trenches, located in the Waste Disposal Trench Area (WDTA), include four northwest-southeast-trending sanitary and industrial waste landfill trenches (covered, but not lined) in which construction debris, incinerated paper, glass, and plastic waste have been deposited. Wastes from the manufacturing of DDT were likely also disposed of in the trenches; however, no discrete areas for DDT waste disposal have been identified (Shaw, 2009d). The landfill, which was active for approximately 10 years, was closed in 1973.

The NDA, located in the northwestern portion of the site, was used to dispose of DDT manufacturing wastes from the Olin Chemical plant. Three waste oil pits measuring approximately 25 by 50 feet were also identified within the NDA in the northwestern portion of RSA-053. As part of the Army's DDT abatement program from 1979 to 1980, 2 feet of surface material from an area within the NDA was excavated from the site and placed in disposal cells at RSA-107, a dedicated ADEM-approved DDT landfill.

The remainder of the site, referred to as Area C, appeared to be undisturbed and relatively free of waste material when investigations began.

**Investigative History.** Environmental investigations were initiated at RSA-053 in 1978 to determine if and to what extent historical site operations had impacted the environment. An RI/feasibility study was performed from 1987 to 1988, and a Phase I and Phase II RFI was performed from 1989 through 1992 and followed up with a site characterization in 1996. A supplemental RI was completed in 2003 and 2004 to fill in data gaps and finalize the draft RI. Additional data gaps and uncertainties were identified during regulatory review of the draft RSA-053 RI report. Additional sampling was performed in 2008 to address these issues and complete the RI. The final RI (Shaw, 2009d) was approved by ADEM on August 14, 2009. A feasibility study was prepared for the site in 2011 (Shaw, 2011b).

**Corrective Measures.** From April 2013 to February 2014, corrective measures activities were implemented at the site to treat contaminated subsurface soil and groundwater resulting in risks to human health and the environment from potential leaching from soil to groundwater and direct contact to subsurface soil. The Army performed corrective measures to treat the contaminated unsaturated zone soils in the WDTA and CBZ DNAPL in the saturated zone and accessible bedrock at RSA-053 to support final site closure at RSA-053. The corrective measure objectives were as follows:

- Reduce or eliminate sourcing to groundwater from contaminants in soil/waste material in the northern WDTA and the southern WDTA.
- Reduce or eliminate industrial (groundskeeper or construction worker) exposure to PAHs, 4,4'-DDT, and 4,4'-DDE in soil.
- Prevent residential use of the WDTA.
- Reduce or eliminate ecological exposure to 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD in WDTA surface soil.
- Reduce or eliminate accessible CBZ DNAPL source material in the saturated soil of the NDA.

The major components of the corrective measures were as follows:

- In situ thermal treatment using electrical resistive heating (ERH) to reduce levels of CBZ DNAPL and source material in the NDA saturated zone (Figure 5-22).
- On-site waste consolidation within the WDTA, moving contaminated soil in the southern portion of the site to the northern portion to remove wastes from contact with groundwater and reduce the landfill footprint. Excavated areas were regraded, backfilled, and revegetated.
- Installation of an engineered cover system over the waste in the northern portion of the WDTA (including the relocated waste) to minimize infiltration of rainwater and reduce leachate production.
- Construction of a surface water control and drainage system to convey water away from the landfill cover, which will eliminate erosion and ensure the long-term integrity of the RSA-053 cover system.
- Installation of landfill monitoring systems, including landfill gas venting and groundwater monitoring well system.

Based on confirmation soil sample results from the landfill consolidation and a combination of groundwater sample results and operational milestones (temperature and mass removal) during in situ thermal treatment, the corrective measures were successful in achieving the remedial objectives. Additionally, an LTM program is being implemented and LUCs are in place for RSA-053, including the NDA, where most of the contaminants were detected.

#### **5.8.1.2 RSA-010**

RSA-010 occupies 66 acres of land near the geographic center of RSA, within the Redstone Arsenal Landfill. RSA-010 is a closed unlined sanitary landfill and permitted RCRA SWMU initially constructed to provide sanitary and municipal waste disposal for tenants residing within

RSA. The site is south of Martin Road and southeast of Mills Road and accessible via Refuge Road near the northern boundary entrance (Figure 5-23).

The sanitary landfill was constructed in 1972, received waste until 1991, and was closed in 1992. Materials disposed of in the closed sanitary landfill included household, administrative, and industrial waste. Waste containing waste lube oil, fuel oil sludge, and sewage treatment grease trap solids was disposed of in the northern portion of the landfill in waste oil pits, and household waste, paper products, hospital infectious waste, construction debris, asbestos, and ash from incinerated paper were disposed of in sanitary trenches (now closed) in the southern and remaining portions of the site. The trenches were later covered with a thin layer of soil.

Currently, a 43.55-acre active C&D landfill (ADEM Permit No. 45-03) is operational and permitted for disposal within the RSA-010 site. Both the closed sanitary landfill and C&D landfill, the surrounding landfill buffer zone, a small area north of Refuge Road used for recycling, a closed SWMU, and the internal boundary roads comprise the 75.96-acre RCRA permitted Redstone Arsenal Landfill (Figure 5-23).

The site is located south of Refuge Road and adjoins RSA-053 to the east. RSA-010 to the south is bordered by the Olin Consent decree area (RSA-101), the Wheeler National Wildlife Reserve, and the floodplains and wetlands of the Huntsville Spring Branch and to the west by MSFC (including the East Test Stand). To the north is the Redstone Arsenal Landfill concrete and asphalt grinding and recycling area, along with heavily wooded portions of MSFC-074 and RSA-183.

In 1976, a 2.5-acre landfill to be used for the disposal of DDT-contaminated soil and sediment was built in the northwest corner of site (Figure 5-23). The 2.5-acre closed DDT soil/debris landfill was part of the original 68.5 acres at the northwest corner of RSA-010 before becoming a separate RCRA SWMU in 1978. This site lies outside the northwest corner of the RSA-010 boundary but is included in the overall Redstone Arsenal Landfill acreage.

Soil and sediment contaminated with DDT were disposed in discrete, clay-lined cells in the DDT landfill as part of the DDT Migration Abatement Program. The DDT Landfill operated from 1979 to 1982, then the site was capped as part of the closure-post closure plan (1983). Each cell was built with a minimum 2-foot-thick, low-permeability clay layer compacted on the bottom and sides. After each cell was filled, it was covered with clay and topsoil. The final cap over each cell consists of a minimum of 2 feet of compacted clay with a permeability of  $1 \times 10^{-7}$  centimeters per second or less. The clay was covered with a minimum of 6 inches of topsoil, fertilized, and seeded. The DDT Landfill is currently a closed SWMU (RSA-107). Removal of the DDT

Landfill from RSA-010 as a separate permitted SWMU reduced the landfill footprint from 68.5 to 66 acres in size.

Closed portions of the landfill include west-east-trending disposal trenches and a rubble fill area located in the southern and southeastern portions of RSA-010. The disposal trenches in this area were approximately 25 feet wide, 400 feet long, and greater than 20 feet deep. Waste disposed was primarily sanitary and municipal. The closed waste oil pits located on the north end of RSA-010 were used to dispose of waste lube oil, boiler plant fuel oil and sludge, oil spill residues, and sewage treatment grease trap solids.

In 1978, the first monitoring wells were installed on the RSA-010 landfill as part of the construction, operation, and monitoring of the DDT Waste Soil Landfill, RSA-107. Additional wells were added to replace damaged wells and monitor the DDT Landfill and portions of the sanitary landfill in 1981 and 1984. The DDT landfill was operated for disposal of DDT-contaminated wastes from areas within RSA that were placed there as a result of the DDT migration abatement program. The first RCRA field investigation at the sanitary landfill began with PELA in 1987 and was completed in 1988. The sanitary landfill stopped receiving waste in 1991 and was closed in 1992.

The Redstone Arsenal Landfill accepted construction/demolition debris under an interim permit from 1992 to 1995. On December 21, 1995 the Alabama Department of Solid Waste issued a final permit (Permit No. 45-03) for operation of the C&D debris landfill, which remains active currently. Long-term compliance monitoring of permitted wells is conducted semiannually, and LUCs are in place. It is anticipated that the construction/demolition landfill will operate for a minimum of 30 years.

The C&D landfill is permitted to accept for disposal asbestos; nonputrescible, nonhazardous C&D waste; and rubbish under ADEM Rule 335-13-1-.03, with an approved average daily volume of 900 tons per day.

During construction of a surface water diversion ditch on June 11, 2015, a partially buried drum containing a small amount of munition-related material was discovered. Results from the initial response report/photographs prepared by RSA personnel plus the final Explosive Ordnance Disposal (EOD) report indicate the drum contained the following group of items:

- Two 76-millimeter projectiles, illumination
- One 105-millimeter projectile (empty)
- One cylinder of propellant
- Six rocket motors

- One M42 submunition (empty)
- Multiple small miscellaneous scrap items (empty).

These items were evaluated by the EOD detachment from Fort Campbell on June 12, 2015, transported by EOD to Test Area 1, and destroyed. The items were encountered adjacent to the southeast corner of RSA-010; it is not known when or how these items came to be disposed at the site.

***Investigative History.*** The following major investigations have been conducted at RSA-010:

- Site investigation (Testing Inc., 1978-1984)
- RI (PELA, 1987-1988)
- Phase I and II RFI (Geraghty & Miller, Inc. 1991-1992)
- Interim corrective measure design (Foster Wheeler, 1994-1995)
- Supplemental groundwater investigation (USACE, 1995)
- Hydrogeologic investigations (GSA, 1996)
- LTM (ICF Kaiser Engineering, 1996-1998)
- RI/Feasibility Study (ICF Kaiser Engineering, 1996-1999)
- LTM (Shaw, 1998-2004)
- Landfill compliance monitoring (Shaw [acquired by CB&I] in 2013, 2005-2014)
- RFI Phase I and II (CB&I, 2013-2017).

### **5.8.2 Hydrogeology**

Groundwater occurs as an unconfined water table aquifer within the overburden and upper bedrock units, with groundwater typically first encountered in the overburden. Groundwater within the overburden and shallow bedrock is hydraulically interconnected. Figure 5-24 presents the potentiometric surface for the shallow unconfined, water table aquifer based on synoptic measurements collected in 2017. Historical water level statistics for each location are provided in Appendix D. Based on water level measurements taken in February 2017, groundwater flow is predominantly southwest for the majority of the area, with a southerly flow on the southern portion of FA-4.

### **5.8.3 Nature and Extent of Contamination**

The current understanding of the nature and extent of contamination within FA-4 is based not only on data collected as part of the RSA-147/148/149 groundwater unit investigations but also on groundwater data collected as part of environmental investigations conducted at surface media sites RSA-053, RSA-083, and RSA-010, which lie within or adjacent to the FA-4 boundary. The surface media site investigations were designed in part to determine contaminant sources and evaluate their potential for impacting groundwater.

A database consisting of the most recent, usable samples collected from groundwater sampling locations within and in close proximity to FA-4 are considered representative of current conditions and used to evaluate the nature and extent of contamination within FA-4 of the RSA-147/148/149 groundwater units. VOC data collected prior to the corrective measures within the ERH treatment area were not considered representative of current site conditions and therefore, were not usable. Usability criteria are discussed in Section 4.2.2. The following sections describe the nature and extent of contamination in groundwater at FA-4.

**DNAPL Occurrence.** As discussed in Section 5.1, DNAPL is suspected near sampling locations where concentrations exceed 10 percent of a contaminant's solubility in water. CBZ was detected at monitoring well 053-RS2004 at a concentration of 53,000 µg/L that exceeded 10 percent of its solubility of 49,800 µg/L. A broader halo exceeding 1 percent of the solubility of CBZ in the shallow groundwater zone reflects the elevated dissolved-phase plume surrounding the DNAPL location (Figure 5-25).

**Dissolved-Phase Contamination.** In the usable FA-4 groundwater data sets that represent current conditions, 25 chemicals and 1 metal have been identified at concentrations that exceed PSVs and, in the case of metals, their BSVs as well (Table 5-7). The 1 metal and 25 chemicals are considered potential site-related contaminants to groundwater and fall within the following analytical suites:

- VOCs (9 compounds)
- Pesticides/PCBs (6 compounds)
- Explosive compounds (10 compounds)
- Metals (1 element).

All site-related chemicals that exceed their PSVs are considered contaminants and evaluated in the following sections. The nature and extent of the contaminants detected in groundwater at concentrations above their PSVs were evaluated using all available information on groundwater flow regimes, including dye trace studies and other hydrogeologic evaluations discussed in Chapter 3.0, as well as distribution maps for every chemical with one or more PSV exceedances to determine lateral and vertical extents of contamination within both the shallow and deep groundwater flow zones.

#### **5.8.3.1 Volatile Organic Compounds in Groundwater**

Nine VOCs were detected at concentrations above their PSVs in groundwater in FA-4 within RSA-147/148/149. The nature and extent of these compounds is presented in the following text, in decreasing order of detection frequency above their PSVs.



**CBZ.** CBZ was released to the environment as part of the disposal of process waste at the NDA within FA-4. CBZ is present in 20 of the 30 samples analyzed for it (Table 5-9). Of the 20 detections, concentrations in 11 samples from wells that monitor shallow flow zone exceeded the PSV (100 µg/L). CBZ was not detected in the one groundwater sample from a spring. The exceedances in shallow groundwater range in concentration from 350 to 50,300 µg/L. The highest concentration of CBZ was identified in well 053-RS2004, located within the NDA. Seven additional wells with CBZ exceedances are located within the NDA. The CBZ plume related to the NDA discrete source area is limited in extent, as shown on Figure 5-26. In situ thermal treatment using ERH was conducted to reduce levels of CBZ DNAPL and source material in the saturated zone within the NDA. An isolated smaller CBZ plume is located on the southeastern portion of FA-4. CBZ concentrations in the shallow flow zone beneath FA-4 are delineated completely by the existing data. Detections where CBZ was either not detected or was detected below the PSV serve to bound all PSV exceedances in shallow zone monitoring wells in all directions: F53-RS270 to the north; wells F53-RS554; F010-RS087 and F10-RS231 to the west and southwest; and F53-RS031, F53-RS033, 053-RS1997, F53-RS335, and F53-RS139 to the east and southeast. Recent sample results indicate CBZ concentrations south of FA-4 are all below the PSV (Figure 5-26).

CBZ exceedances were detected in bedrock wells 053-RS2175 and 053-RS2176 at depths of 91 feet for both wells. CBZ was not detected at concentrations exceeding the PSV in the most recent samples from two deeper bedrock wells F53-RS355 (156 feet bgs), and F53-RS357 (149 feet bgs) within FA-4 or F10-RS399 (136 feet bgs) and F10-RS491 (147 feet bgs) located downgradient, just outside the FA-4 boundary (Table 5-10; Figure 5-27). Dissolved CBZ plumes of any extent do not appear to exist in the deep zone. The lateral and vertical extent of CBZ in the vicinity of FA-4 is delineated.

**TCE.** TCE is present in 12 of the 33 samples analyzed for it (Table 5-7). Of the 12 detections, TCE was detected at concentrations exceeding the PSV (5 µg/L) in five monitoring wells within the shallow zone in FA-4. Exceedances in the shallow groundwater range in concentration from 5.4 to 752 µg/L. In the northern portion of FA-4, TCE exceedances are clustered within the NDA (053-RS1999 [46.6 µg/L], 053-RS2000 [752 µg/L], 053-RS2001 [5.4 µg/L]), resulting in a plume area of a limited extent (Figure 5-28). Within the southern portion of FA-4, PSV exceedances at wells F53-RS277 (25 µg/L) and F10-RS231 (7.23 µg/L) are part of a much larger TCE plume. While historical disposal activities have likely been a source of release for the localized TCE plume within the NDA, several lines of evidence support that there are commingled plumes in the southern portion of RSA-053. Dye trace studies conducted within RSA-148 groundwater unit confirm that groundwater movement occurs along flowpaths in the

bedrock and deep bedrock that extend from source areas within RSA-148 and RSA-149, some located thousands of feet away, to monitoring wells at and in the vicinity of RSA-053 (Shaw, 2003a) (Figure 5-28). A localized release of TCE has been recorded at RSA-010, located immediately west of FA-4. TCE exceedances have been detected in several monitoring wells (F10-RS398, F10-RS490, and F10-RS231) within RSA-010 in the immediate vicinity of FA-4. As shown on Figure 5-28, dye tracing results associated with upgradient injections indicate that releases at MSFC source areas likely contributed to the TCE plume in the south. TCE plumes originating from NASA sources within MSFC have migrated beyond the MSFC physical boundary and have contributed to groundwater contamination beneath RSA-053 and adjacent RSA-010 (CB&I, 2017).

The northern TCE plume within the NDA is bounded in all directions by wells in which TCE was either not detected or was detected below the PSV: F53-RS349, F53-RS270, and spring RSP-1075a to the north; piezometer F53-PZ18 and well F53-RS554 to the west; F53-RS359 and F53-RS271 to the south; F53-RS033 and F53-RS275 to the southeast; and piezometer F53-PZ13 and F53-RS031 to the east.

TCE was not detected in the samples from the two deep bedrock wells (F53-RS355 [156 feet bgs] and F53-RS357 [149 feet bgs]) within FA-4 (Figure 5-27; Table 5-10). However, TCE exceedances were detected at concentrations exceeding the PSV in the most recent samples from two deep bedrock wells F10-RS399 (136 feet bgs) and F10-RS491 (147 feet bgs) located just outside the FA-4 boundary, confirming that groundwater movement is occurring along flowpaths in the deep bedrock extending from source areas within RSA-148 and RSA-149. RSA-010 has assumed the responsibility for groundwater action for TCE in the deep bedrock within these areas (CB&I, 2017).

**Chloroform.** Chloroform is present in groundwater within FA-4 as a result of disposal of wastes associated with manufacturing DDT. Chloroform is present in 20 of the 33 samples analyzed for it (Table 5-9). Of the 20 detections, concentrations in only 8 samples in the shallow zone wells exceeded the PSV (80 µg/L). Shallow groundwater chloroform exceedances range in concentration from 100 to 4360 µg/L. Chloroform exceedances are localized in the northern portion of FA-4 and of limited extent within the NDA. Plume dispersion from the source area appears to be very limited, as shown on Figure 5-29. The chloroform plume is bounded in all directions by wells in which chloroform was either not detected or was detected below the PSV: F53-RS347 and F53-RS346 to the north; F53-RS349 and F53-RS348 to the northeast; spring RSP-1075a to the northwest; piezometer F53-PZ18 and well F53-RS554 to the west and southwest, respectively; F53-RS359 and F53-RS271 to the south; F53-RS033 and F53-RS275 to the southeast; and piezometers F53-PZ13, F53-RS031, and F53-RS333 to the east (Figure 5-29).

As shown in the analytical summary of deep zone sampling results presented on Table 5-10, chloroform was not detected above screening criteria in recent groundwater samples from the wells in the deep groundwater flow zone (F53-RS355 [156 feet bgs], and F53-RS357 [149 feet bgs], shown on Figure 5-27). Dissolved chloroform plumes of any extent do not appear to exist in the deep zone. The vertical lateral and vertical extent of chloroform in the vicinity of FA-4 is completely delineated.

**Methylene Chloride.** Methylene chloride (MC) is a product of the degradation of CT and chloroform. MC was detected in 8 of the 27 samples analyzed, of which 7 samples exceed the PSV (5 µg/L) (Table 5-9). Samples that exceed the PSV are from the shallow groundwater zone. MC exceedances range in concentration from 43.5 to 6160 µg/L. The MC plume area coincides with the areas of high CBZ and chloroform concentrations within the NDA. The MC plume is bounded in all directions by wells in which MC was either not detected or was detected below the PSV: F53-RS347 and F53-RS346 to the north, F53-RS349 to the northeast, spring RSP-1075a to the northwest, piezometer F53-PZ18 and well F53-RS554 to the west, F53-RS271 to the south, F53-RS033 and F53-RS275 to the southeast, and piezometer F53-PZ13 to the east (Figure 5-30).

MC was not detected above the PSV in groundwater samples collected from a spring or deep groundwater flow zone within FA-4 and the immediate vicinity (Figure 5-27; Table 5-10). Dissolved MC plumes of any extent do not appear to exist in the deep zone. The lateral and vertical extent of MC in the vicinity of FA-4 is completely delineated.

**Benzene.** Benzene was detected in 11 of the 34 most recent samples analyzed for it; 4 detections exceed the PSV (5 µg/L). Benzene exceedances were all detected in shallow zone wells at concentrations ranging from 28 to 187 µg/L. The benzene plume is limited in extent and encompassed within the extent of the CBZ plume within the NDA (Figure 5-31). Both contaminants are present as a result of disposal of DDT process waste at the NDA. Benzene appears to be related to degradation of CBZ. Benzene was not detected in the spring and deep bedrock well samples. The extent of benzene is delineated by wells in which benzene was either not detected or was detected below the PSV: F53-RS270 to the north; piezometer F53-PZ18 and wells F53-RS032, 053-RS1999, and 053-RS2002 to the west and southwest; F53-PZ14 to the south; piezometer F53-PZ13 to the east; and F53-RS031 to the northeast (Figure 5-31).

Benzene was not detected in groundwater samples collected from a spring or deep groundwater flow zone within FA-4 and the adjacent sites (F53-RS333, F53-RS355, F53-RS357, F10-RS399, and F10-RS491) (Figure 5-27; Table 5-10). Dissolved benzene plumes of any extent do not

appear to exist in the deep zone. The lateral and vertical extent of benzene in the vicinity of FA-4 is completely delineated.

**1,1,2,2-TeCA.** 1,1,2,2- TeCA is a solvent and degreasing agent often detected as a collocated contaminant with TCE. It was also a component of a mustard decontaminating process. 1,1,2,2-TeCA was detected in only 2 of the 24 most recent samples analyzed for it; however, both detections exceed the very low PSV (0.076 µg/L). Both exceedances were detected in the shallow zone wells collocated with the large southern TCE plume. Except for the two wells in the southern portion, 1,1,2,2-TeCA was not detected or was detected below the PSV in all of the other wells within FA-4. These southernmost wells lie within the flowpath of dye detection associated with upgradient injections in the vicinity of MSFC-034. As discussed previously, an evaluation of dye tracing results indicates long flowpaths extend from upgradient sources to southern plumes of TCE and 1,1,2,2-TeCA (Figure 5-32). The responsibility for groundwater action for 1,1,2,2-TeCA in shallow groundwater zone in this southern area has been assumed by RSA-010 (CB&I, 2017).

**1,1-Dichloroethane.** 1,1-Dichloroethane (DCA) was detected in 9 of the 33 most recent samples analyzed for it (Table 5-7). 1,1-DCA exceeds the 2.8 µg/L PSV in two shallow zone monitoring wells (F10-RS087 and F53-RS554) at concentrations of 37.3 and 12.7 µg/L, respectively. The two wells with 1,1-DCA exceedances are located along the eastern boundary of RSA-010. Delineation of contaminants within the RSA-010 surface media site is the responsibility of RSA-010. The two wells are bounded within FA-4 by wells in which 1,1-DCA was either not detected or was detected below the PSV: piezometer F53-PZ18 and well 053-RS1999 to the north and northeast, respectively; F53-PZ15, F53-RS359, F53-RS271, and piezometer F53-PZ09 to the east; F53-RS277 to the southeast; and F10-RS231 and 010-RS2363 to the south and southwest (Figure 5-33). 1,1-DCA was not detected in deep groundwater samples (F53-RS333, F53-RS355, F53-RS357, F10-RS399, and F10-RS491 and groundwater from a spring (RSP-1075a) (Figure 5-27; Table 5-10). The lateral and vertical extent of 1,1-DCA in the vicinity of FA-4 is completely delineated.

**Acetone.** Acetone was detected in 4 of the 36 most recent samples analyzed for it; 1 detection exceeds the PSV (1400 µg/L). The acetone exceedance was detected in shallow zone well 053-RS2000 at a concentration of 2410 µg/L. Well 053-RS2000 is located within the NDA (Figure 5-33). The isolated exceedance is bounded in all directions by wells in which acetone was either not detected or was detected below the PSV. Acetone was not detected in deep groundwater samples (Figure 5-27; Table 5-10).

**Vinyl Chloride.** Vinyl chloride (VC) is usually present in groundwater as a result of the reductive dechlorination of TCE. VC was detected in 5 of the 31 most recent samples analyzed for it; 1 detection exceeds the PSV (2 µg/L). The VC exceedance was detected in the overburden shallow zone well F10-RS087, located along the eastern boundary of RSA-010, at a concentration of 3.42 µg/L (Figure 5-33). VC was not detected in deep groundwater samples (Figure 5-27; Table 5-10). The responsibility for groundwater action for VC in shallow groundwater zone in this area has been assumed by RSA-010 (CB&I, 2017).

#### **5.8.3.2 Explosive Compounds in Groundwater**

Ten explosive compounds were detected at concentrations above their respective PSVs in one or more of the usable, most recent FA-4 groundwater samples. The nature and extent of these compounds is presented in the following text, in decreasing order of detection frequency above their PSV.

**2-Nitrotoluene.** 2-Nitrotoluene (NT) was detected in 4 of the 15 most recent groundwater samples analyzed for it. All four detections exceed the PSV of 0.31 µg/L (Table 5-9). The four exceedances range in concentration from 1 to 14.6 µg/L. The two highest exceedances are located in the overburden shallow zone: F10-RS087 (14.6 µg/L) and F53-RS554 (13.4 µg/L) along the eastern boundary of RSA-010. The remaining two exceedances are located within the shallow zone. There are two 2-NT plumes within adjacent RSA-010: one smaller plume located on the northwestern corner of the landfill and a larger plume located on the southern and eastern portion extending into the central and southwestern portion of FA-4, forming an overlapping plume spanning both sites within the shallow zone (Figure 5-34). 2-NT was not detected in the deep groundwater samples. As shown on Figure 5-34, the lateral extent of 2-NT is delineated to the north by wells 010-RS2367, spring RSP-1075a, F53-RS270, F53-RS349, and spring RSP-1075a and to the east and south by wells F53-RS274, F53-RS192, F53-RS277, F-53-RS193, and F10-RS094 and spring RSP-1126. RSA-010 has assumed responsibility for the 2-NT in groundwater in this area (CB&I, 2017). Since 2-NT was not detected in deep bedrock wells F53-RS333, F53-RS355 and F10-RS491 (Figure 5-27; Table 5-10), the vertical extent of 2-NT in groundwater is delineated.

Except for 2-NT, all the other explosive compounds described in the following sections were detected in the northern portion of FA-4, within the NDA. These compounds were detected at concentrations exceeding their PSVs within the same wells located in the shallow zone. None of the explosive compounds were detected in the deep bedrock wells at concentrations exceeding their PSVs (Figure 5-27; Table 5-10). Therefore, the lateral extent of these explosive compounds is delineated by the same wells in which they were not detected or were detected below their PSVs: F53-RS270 to the north; spring RSP-1075a to the northwest; F10-RS077 and F53-RS554

to the west and southwest, respectively; F53-RS271 and F53-RS359 to the south; F53-RS275 to the southeast; and F53-RS031 to the northeast (Figure 5-35). Since these compounds were not detected in the deep bedrock wells (F53-RS333, F10-RS398, and F53-RS355), their vertical extent is delineated. Both the lateral and vertical extent of the explosive compounds in groundwater is completely delineated.

**2,4-Dinitrotoluene.** 2,4-DNT was detected in 3 of the 16 most recent groundwater samples analyzed for it. Two of the three detections exceed the PSV of 0.11 µg/L. The exceedances were detected in the shallow zone within the NDA (Figure 5-35).

**2-Amino-4,6-Dinitrotoluene and 4-Amino-2,6-Dinitrotoluene.** These compounds are discussed together because of their chemical similarities and their common occurrence in the groundwater data set. 2-Amino-4,6-dinitrotoluene (2-ADNT) was detected in 4 of the 17 most recent groundwater samples analyzed for it. 2-ADNT concentrations in two shallow zone wells 053-RS2175 (43.4 µg/L) and 053-RS2176 (269 µg/L) exceed the PSV of 3.9 µg/L. Both wells are located within the NDA (Figure 5-35). 2-ADNT was not detected in spring water or the deep bedrock wells; F53-RS333, F10-RS398, and F53-RS355.

4-Amino-2,6-dinitrotoluene (4-ADNT) shows a similar distribution to 2-ADNT. It was detected in 4 of 15 samples; two results (both shallow) exceeded the PSV of 3.9 µg/L. Both wells with 4-ADNT exceedances (053-RS2175 [10 µg/L], and 053-RS2176 [72.9 µg/L]) are located within the NDA. There were no detections of this compound in spring water or deep bedrock wells (Table 5-9).

**RDX.** RDX was detected in 3 of 17 most recent groundwater samples. Of the three detections, two shallow zone samples exceed the PSV of 0.7 µg/L. The wells with RDX exceedances (053-RS2175 [0.897 µg/L] and 053-RS2176 [106 µg/L]) are located within the NDA (Figure 5-35). There were no detections of this compound in spring water or deep bedrock wells.

**3-Nitrotoluene.** 3-NT was detected in 1 of 16 most recent groundwater samples. The shallow zone sample 053-RS2175 (1.04 µg/L) detection exceeds the PSV of 0.17 µg/L. The 3-NT exceedance is located within the NDA (Figure 5-35). 3-NT was not detected in spring water or deep bedrock wells.

**Nitroglycerin.** Nitroglycerin was detected in 1 of 11 most recent groundwater samples. The shallow zone sample 053-RS2175 (48.3 µg/L) detection exceeds the PSV of 0.2 µg/L. The well with the 3-NT exceedance is located within the NDA (Figure 5-35). Nitroglycerin was not detected in spring water or deep bedrock wells.

**PETN.** PETN was detected in 4 of 14 most recent groundwater samples. Of the four detections, only one shallow zone sample at a concentration of 5.02 µg/L exceeds the PSV of 3.9 µg/L. The well with PETN exceedance (053-RS2176) is located within the NDA (Figure 5-35). There were no detections of this compound in spring water or deep bedrock wells.

**1,3-Dinitrobenzene.** 1,3-Dinitrobenzene was detected in 1 of 15 most recent groundwater samples. Both detections exceed the PSV of 0.2 µg/L. The well with the 1,3-dinitrobenzene exceedance (053-RS2176) (11.3 µg/L) is a shallow zone well located within the NDA (Figure 5-35). There were no detections of this compound in spring water or deep bedrock wells.

**2,4,6-Trinitrotoluene.** 2,4,6-Trinitrotoluene was detected in 1 of 18 most recent groundwater samples. One shallow zone sample at a concentration of 2.24 µg/L exceeds the PSV of 0.98 µg/L. The well with the 2,4,6-trinitrotoluene exceedance (053-RS2176) is located within the NDA (Figure 5-35). There were no detections of this compound in spring water or deep bedrock wells.

Except for 2-NT, all the other nine explosive compounds that were detected at concentrations exceeding the PSVs were detected in the shallow bedrock wells. Exceedances were not detected in the overburden wells or deeper bedrock wells.

#### **5.8.3.3 Pesticide Compounds in Groundwater**

A total of six pesticides were detected at concentrations above their PSVs in recent usable groundwater samples at FA-4 (Table 5-9). The nature and extent of each pesticide that exceeded its PSV for groundwater is discussed below in order of the most frequent exceedances first.

**Beta-BHC.** beta-BHC was detected in 10 shallow zone groundwater samples, 6 of which had concentrations that exceeded the PSV. The exceedances for beta-BHC ranged from 0.03 to 0.0379 µg/L. As shown on Figure 5-36, there are two distinct beta-BHC plumes located in the central portion and the southern portion of FA-4. The central plume extends from FA-4 eastward into adjacent RSA-028 and southeast into RSA-E. The southern plume commingles with a plume on the southern portion of RSA-010. Both shallow groundwater flow zone plumes are bounded on all sides with sample locations that did not contain detectable beta-BHC or that showed a detected concentration below the PSV. The central plume is bounded to the north by wells F53-RS270, F53-RS349, F53-RS351, and F53-RS354; to the east by F53-RS352, F53-RS353, FE-RS1444, and F53-RS279; to the south and southwest by F53-PZ01, F53-PZ03, F53-PZ06, 053-RS1997, and F10-RS087; and to the west by F53-PZ18, F10-RS077, and F10-RS398. The southern plume is bounded to the north by F53-RS277 and F10-RS087; to the east by F53-PZ03, F53-PZ04, spring RSP-1195, F10-RS089, and F53-RS179; to the south by spring RSP-1126 and

F10-RS493; to the west by 010-RS2365, F10-RS172, and F10-RS078; and to the northwest by 010-RS2361 and 010-RS2362. There were no detections of this compound in spring water or deep bedrock wells (F53-RS355 and F53-RS357) (Figure 5-27; Table 5-10). Both the lateral and vertical extent of the beta-BHC in groundwater is completely delineated.

***Dieldrin.*** Dieldrin was detected in shallow zone groundwater in 2 of the 28 locations recently sampled at FA-4, and both detections exceeded the very low PSV (0.0018 µg/L). The dieldrin plume extends from the NDA southeast to the WDTAs, most likely from past historical disposal activities (Figure 5-37). The dieldrin plume within FA-4 is bounded on all sides with sample locations that did not contain detectable dieldrin or that showed a detected concentration below the PSV. The plume is bounded to the north by wells F53-RS270 and F53-RS349; to the east by F53-RS350, F53-RS351, F53-PZ13, F53-PZ14, and F53-PZ15; to the southeast by F53-RS033, 053-RS1997, and F53-PZ09; to the south by F10-RS087; and to the west and northwest by F53-RS554, F10-RS077, and RSP-1075a. There were no detections of this compound in spring water or deep bedrock wells (Figure 5-27; Table 5-10). Both the lateral and vertical extent of the beta-BHC in groundwater is completely delineated.

***4,4'-DDE.*** 4,4'-DDE was detected in 5 of the 26 recent shallow zone groundwater samples; concentrations in 2 of the samples exceeded the PSV of 0.046 µg/L (Table 5-9). The exceedances for 4,4'-DDE ranged from 0.0889 to 0.524 µg/L. As shown on Figure 5-38, the 4,4'-DDE plume is confined to the NDA within FA-4. The lateral extent of 4,4'-DDE is delineated by wells F53-RS270 to the north; spring RSP-1075a to the northwest; F10-RS077 and F53-RS554 to the west and southwest, respectively; F53-RS271 and F53-RS359 to the south; F53-PZ14 and F53-PZ15 to the southeast; and F53-RS031 to the northeast. Since 4,4'-DDE was not detected in the deep bedrock wells (F53-RS333, F10-RS398, and F53-RS355), the vertical extent is delineated (Figure 5-27; Table 5-10). Both the lateral and vertical extent of 4,4'-DDE in groundwater is completely delineated.

***4,4'-DDD.*** 4,4'-DDD was detected in 1 of the 24 recent shallow zone groundwater samples. The single detection at 053-RS2003 (0.535 µg/L) exceeds the PSV of 0.032 µg/L (Table 5-9). As shown on Figure 5-39, the detection is located within the NDA. Previous data (spring 2015) indicate that the 4,4'-DDD detected in the NDA was a part of the plume originating from upgradient sources within RSA-252. The single isolated 4,4'-DDD exceedance within FA-4 is surrounded by wells that did not contain detectable 4,4'-DDD or that showed a detected concentration below the PSV: F53-RS270 to the north; spring RSP-1075a to the northwest; F53-RS191, F10-RS077, and F53-RS554 to the west and southwest; F53-PZ15, F53-RS271, and F53-RS359 to the south; F53-RS033 and F53-PZ12 to the southeast; and F53-RS031 to the northeast. Since 4,4'-DDD was not detected in the deep bedrock wells (F53-RS333, F10-RS398,



and F53-RS355), the vertical extent is delineated. Both the lateral and vertical extent of 4,4'-DDD in groundwater is completely delineated.

**alpha-BHC.** Alpha-BHC was detected in 4 of the 27 recent shallow zone groundwater samples. One sample (053-RS2003) at a concentration of 0.0542 µg/L exceeds the PSV of 0.0072 µg/L (Table 5-9). As shown on Figure 5-40, the detection was located within the NDA within FA-4. The isolated detection of alpha-BHC is surrounded by wells that did not contain detectable alpha-BHC or that showed a detected concentration below the PSV: F53-RS270 to the north; spring RSP-1075a to the northwest; F53-PZ18, F53-PZ17, F10-RS077, and F53-RS554 to the west and southwest; F53-PZ15, F53-RS271, and F53-RS359 to the south; F53-PZ14 and F53-RS033 to the southeast; F53-PZ13 to the east; and F53-RS031 to the northeast. Since alpha-BHC was not detected in the deep bedrock wells (F53-RS333, F10-RS398, and F53-RS355), the vertical extent is delineated (Figure 5-27; Table 5-10). Both the lateral and vertical extent of alpha-BHC in groundwater is completely delineated.

**Aldrin.** Aldrin was detected in 1 of the 21 recent shallow zone groundwater samples; the detection (0.05 µg/L) exceeds the PSV of 0.00092 µg/L (Table 5-9). The aldrin detection is part of a shallow zone groundwater plume that extends southeast into RSA-028 and RSA-E (Figure 5-41). The lateral extent of the aldrin plume is delineated by wells 053-RS2175, 053-RS2176, F53-RS033, F53-RS275, and F53-RS351 to the north; spring RSP-1075a, 010-RS2366, and 010-RS2367 to the northwest; F10-RS087, F53-RS277, 053-RS1997, F53-RS193, and F53-RS335 to the west; F10-RS089, spring RSP-1209, F53-RS358, and F53-RS196 to the south; and F53-RS279, FE-RS1444, and FE-RS1445 to the east. Since aldrin was not detected in the deep bedrock wells (F53-RS333, F10-RS398, and F53-RS355), the vertical extent is delineated (Figure 5-27; Table 5-10). Both the lateral and vertical extent of aldrin in groundwater is completely delineated.

#### **5.8.3.4 Metals Compounds in Groundwater**

Metals are detected in groundwater at concentrations exceeding their PSVs and BSVs; however, as explained in Section 5.2, metals also exist as natural constituents of soil and groundwater. Therefore, metals concentrations in these media were evaluated using statistical and geochemical methods to determine whether a particular metal concentration is naturally occurring or is potential site-related contamination. The nature and extent evaluation portrays current conditions and utilizes the most recent analytical result from each location for each parameter.

Metals concentrations are considered to be contamination only if the concentration exceeds the PSV and BSV and are identified in the site-to-background evaluation as anomalous. Table 5-2

lists those locations where metals in most recent samples were detected at concentrations exceeding PSVs and BSVs and identified as statistically and geochemically anomalous.

From examination of Table 5-2, manganese was the only metal detected within FA-4 in a sample from well F53-RS359 at a concentration of 5700 µg/L that exceed the PSV and BSV and cannot be considered naturally occurring. This occurrence of anomalous manganese is isolated in the shallow zone and not as a plume of any extent (Figure 5-42).

#### **5.8.4 Summary and Conclusions**

VOCs, explosive compounds, and pesticides have been identified at FA-4 at concentrations above PSVs; CBZ has also been found at concentrations indicative of the presence of DNAPL within the NDA. Manganese is the only metal detected at anomalous concentrations in an isolated occurrence. Dissolved-phase contamination forms plume areas within the shallow flow zone. Except for TCE exceedances in samples from two deep bedrock wells located just outside the FA-4 boundary within RSA-010, no other compound was detected in the deep bedrock wells. RSA-010 has assumed the responsibility for groundwater action for TCE in the deep bedrock. Dissolved CBZ plumes of any extent do not appear to exist in the deep zone within FA-4.

The following key points summarize the nature and extent of contamination in FA-4 groundwater:

- A total of nine VOCs were detected in groundwater samples at concentrations that exceed their PSVs. CBZ was the only VOC detected at concentrations indicative of DNAPL within the NDA.
- TCE and 1,1,2,2-TeCA are the most widespread exceedances creating the most laterally collocated extensive plumes comingled with RSA-010 plumes. The plumes lie within the groundwater flowpaths of dye detection associated with upgradient sources. The responsibility for groundwater action for TCE and 1,1,2,2-TeCA in shallow groundwater zone in this area has been assumed by RSA-010.
- Plume areas created by other VOC contaminants (CBZ, chloroform, MC, and benzene) are of limited extent and are confined to the NDA. All VOC contaminants are delineated in the shallow flow zones by well locations where concentrations are below the PSV or are not detected.
- Ten explosive compounds were detected in shallow zone groundwater samples at concentrations that exceed their PSVs. An extensive 2-NT plume originates from RSA-010, extending into FA-4 and spanning both sites within the shallow zone. RSA-010 has assumed responsibility for the 2-NT in groundwater in this area. Except for 2-NT, all the other 10 explosive compounds exceedances were limited in extent and confined to the NDA. All shallow groundwater flow zone explosive compound

contaminants are bounded on all sides with sample locations that did not contain detectable compounds or that showed a detected concentration below the PSV.

- A total of six pesticides were detected in shallow zone groundwater samples at concentrations above their PSVs. Except for aldrin and beta-BHC, the other four pesticides are clustered and localized within the NDA. Aldrin and beta-BHC plumes extend beyond FA-4, commingling with plumes within RSA-010. Pesticide exceedances in shallow zone groundwater are delineated by locations where they were found to be below PSVs or were not detected.
- Manganese was the only metal determined to be anomalous and indicative of contamination in a single detection.
- Dissolved-phase contaminants of any extent do not appear to exist in the spring samples or deep zone. Both the lateral and vertical extent of groundwater contamination in FA-4 is completely delineated.
- An LTM program is being implemented and LUCs are in place for RSA-053, including the NDA, where most of the contaminants were detected. A compliance monitoring program and LUCs are also in place at RSA-010.

Relevant COCs for FA-4 and the Army's plan for addressing these COCs are summarized below:

			Unit or Site Responsible for Addressing Groundwater COCs/COACs	
Focus Area	SWMUs	Relevant Groundwater COCs	Delineation	Remedy
4	RSA-010 RSA-053	TCE 1,1,2,2-TeCA VC	RSA-010 MSFC-034	RSA-010 NASA
		TCE CBZ Benzene Chloroform MC Acetone 1,1-DCA 2-NT 3-NT 1,3-Dinitrobenzene 2,4,6-Trinitrotoluene 2,4-DNT 2-ADNT 4-ADNT Nitroglycerin PETN RDX 4,4'-DDE Dieldrin alpha-BHC	RSA-053	RSA-053
		4,4'-DDD	RSA-252	RSA-252
		beta-BHC 2-NT Aldrin	RSA-148	RSA-148

## **5.9 Focus Area 5**

FA-5 encompasses the northern and central portions of RSA-183 to include the former lewisite manufacturing operations area. The former lewisite manufacturing operations area is located to the west of Toftoy Thruway and north of Digney Road (Figure 5-43). FA-5 falls within the RSA-148 groundwater unit, which also encompasses other surface sites within the area.

### **5.9.1 Site Description and History**

FA-5 consists of an area formerly occupied by plants that manufactured lewisite and its raw materials and extends southward to include a large sinkhole drainage area. The FA-5 boundary encompasses all of the area where the RSA-183 surface media are known or suspected to be contaminated as a result of manufacturing operations at the former lewisite plants.

Within FA-5 are two former lewisite manufacturing plants, an abandoned industrial sewer system (a separate site, MSFC-052a), a former motor pool (Building 4381, post-lewisite manufacturing), a former cement plant sump (RSA-123 [NFA]), a former chemical storage warehouse (Building 4496, post-lewisite manufacturing), former dry goods storage (Building 4497, post-lewisite manufacturing), and a drainage ditch system that is coincident with a long, north-south-trending sinkhole (Figure 5-43). A now-capped arsenic waste lagoon (RSA-049) received liquid wastes generated by the manufacturing process.

#### **5.9.1.1 Lewisite Plants Operations (Plants Area)**

The lewisite plants (Plants #1 and #2 on Figure 5-44) were the first two of six constructed at RSA. Although lewisite manufacturing had ceased by late 1943, most buildings were still present and open disposal ponds were still visible in 1950 (Shaw, 2007b). Gradual demolition of the buildings occurred between 1950 and 1976. The Plants Area was overgrown by 1983, with only the abandoned industrial sewer line, the faint outline of the road to the east of Plant 1, and the eastern collection pit remaining as remnants of the plants.

Lewisite was manufactured by reacting AT with acetylene in the presence of mercuric chloride as a catalyst. Further distillation of the crude lewisite resulted in distilled lewisite, which was then placed into containers for transport, possibly by rail, to munitions filling buildings elsewhere at RSA. Chemicals noted in historical documents as related to lewisite production include arsenious oxide, AT, acetylene, carbide, sulfuric acid, CT, caustic soda (used in decontamination), slaked lime, and mercuric chloride.

AT was manufactured at a centralized location (RSA-122) for use at the six lewisite plants, while acetylene was produced on site at each plant. AT was transported to the lewisite plants in rail

cars. Acetylene was generated by reacting calcium carbide with water. This process produced large quantities of lime sludge waste. Arsenic-laden waste generated from lewisite manufacture and lime sludge, a by-product of acetylene generation, were pumped separately to a treatment system, mixed, and discharged to the disposal ponds at RSA-049.

A network of below-ground structures served the lewisite plants, including blowcase pits/sumps, the main collecting pits, floor trenches, industrial sewer lines, chemical transfer piping, storage tanks, waste disposal lagoons, petroleum piping, and wash rack sump. Historical documents indicate that liquid waste from the plants was either pumped to the disposal ponds or released into the industrial sewer. A connection was also noted from the disposal ponds to the industrial sewer system, perhaps to allow for overflow.

Underground pipes were extensively used for transferring liquid chemicals or waste among buildings and to the collecting pit. Although the composition of some of the underground pipes is not known, some of the pipes are shown in engineering drawings as 2-inch- to 6-inch-diameter cast-iron pipes.

**Former Corrosion Treatment Laboratory and Motor Pool (Building 4381).** The former corrosion treatment laboratory and motor pool was located east of lewisite plant 2 (Figure 5-44). Engineering drawings indicate that the corrosion treatment laboratory included a salt fog room, a plating area, a pressure blast area, a darkroom, a humidity test cabinet, a pressure blast unit, an electron microscope room, and an office area (Shaw, 2007b). Discharge from this facility was via 1-inch and 4-inch pipes to the existing ditch on the east side of the facility. The 1-inch pipe conveyed discharge from the pressure blast unit and the 4-inch pipe conveyed discharge from other areas within the building.

No detailed records of motor pool activities at Building 4381 are available, with the exception of an engineering drawing showing a wash rack and sump with discharge into the existing drainage ditch on the east side of the facility (Shaw, 2007b). Removal of a 10,000-gallon underground storage tank in October 1996 was also noted.

**RSA-123, Inactive Cement Plant Sump.** This NFA site is the area of an in-ground sump associated with a former cement mixing plant located west of the lewisite plants area. The plant was reported to have been active in the 1950s (ADEM, 2008). The sump discharged through a 1¼ - inch pipe to open ground west of the sump pad. A review of the area showed no stressed vegetation, soil staining, or other indication of a contaminant release.

**Former Warehouse (Building 4496).** Former warehouse Building 4496 was located southeast of the lewisite plant area (Figure 5-44). Engineering drawings designated this facility

as a warehouse in 1950, functioning as a chemical storage facility with individual areas for glassware, chemicals, equipment, an office, and “dry” areas (Shaw, 2007). No discharge points are shown on reviewed engineering drawings.

Documentation to support the disposal or release of liquid waste to the surface drainage features in the Building 4496 area has not been identified. However, lack of documentation in support of liquid waste release should not imply that this never occurred (Shaw, 2007b). Contaminants identified within the Sinkhole Area of RSA-183 were potentially transported as a result of overland flow of contaminated soil into the surface drainage feature and thereby transported to this area.

***Sinkhole/Drainage Ditch Area.*** The sinkhole/drainage ditch area includes the central and southern portion of RSA-183, from the confluence of the drainage ditches within the Plants Area south to just past Refuge Road (Figure 5-43). The Sinkhole Area is a trough-like, north-south-trending sinkhole approximately 8 feet deep. The area becomes inundated in the wetter winter months and retains water, which then drains/infiltrates into the subsurface karst features. No process development has occurred in the Sinkhole Area.

***RSA-049, Capped Arsenic Waste Lagoons - West, Area F.*** The RSA-049 site encompasses 12.6 acres and included three former open waste ponds that covered approximately 3.2 acres of the site. The unlined ponds were constructed in the 1940s as waste collection and treatment units for lewisite manufacturing Plants 1 and 2. The ponds were backfilled in 1977 with soil from an area west of RSA-049 and then revegetated. In 1997, after a RCRA interim corrective measure was performed, a multilayer RCRA-type cap was installed over the waste ponds and associated contaminated areas (CB&I, 2014).

### ***5.9.2 Previous Investigations and Corrective Measures***

The following investigation activities and corrective measures were conducted within FA-5.

***Investigative History.*** Environmental investigations have been conducted within the Former Lewisite Manufacturing Plants Area No. 1 and 2 since 1979, focusing primarily on RSA-049 and RSA-183. In 1970, the U.S. Army Environmental Hygiene Agency sampled a drainage south of RSA-049. In 1979, a geohydrology characterization survey was completed by TESTING, Inc. In 1988 and 1989, PELA collected groundwater samples. G&M installed eight new monitoring wells in 1992 and 1993; sampled new and existing wells; and collected surface and subsurface soil samples, sediment samples, and soil gas samples. In addition, G&M also completed a geophysical survey. In 1994, Foster Wheeler, EBASCO, and the USACE collected soils data at RSA-049 to support cap design. LTM, including groundwater, soil, and sediment sampling, was

conducted by IT in 1998 and 1999. Supplemental RI activities were conducted by IT in 2000 and 2001. Phase II RI activities were conducted by Shaw in 2003-2006 (Shaw, 2007b).

**Corrective Measures.** Subsequent to the 2007 RI report, a feasibility study was completed to address elevated arsenic and mercury in surface soil in the Plants Area at RSA-183 (Shaw, 2009e). Of the various remedies evaluated in the feasibility study, the record of decision selected soil excavation, treatment, offsite disposal, backfill, short-term sediment and groundwater monitoring, and institutional controls to address the impacted surface soils (Shaw, 2009f). In 2010, approximately 10,334 tons of surface soil was removed and disposed of off site (Shaw, 2011a). The excavated areas were backfilled to original grade. Confirmation sampling was conducted with the cleanup goal of 95 percent of the upper confidence level of the mean greater than or equal to 15 milligrams per kilogram of arsenic. The sampling protocol was determined by ADEM to be insufficient as it could leave in place arsenic in surface soils at levels above 15 milligrams per kilogram. Additional work to address surface metals was detailed in the *Corrective Measures Implementation/Remedial Action Work Plan, RSA-183, Former Lewisite Manufacturing Plants 1 and 2, Operable Unit 05, Redstone Arsenal, Madison County, Alabama* (CB&I, 2015b).

### 5.9.3 Hydrogeology

Groundwater occurs as an unconfined water table aquifer within the overburden and upper bedrock units, with groundwater typically first encountered in the overburden. Groundwater within the overburden and shallow bedrock is hydraulically interconnected. Lenses of clayey sands and gravel, typically on the order of 2 to 3 feet thick and up to 12 feet, were observed within the overburden at RSA-183 (Figure 5-45). These lenses are discontinuous across the site and are sometimes partially saturated, resulting in a perched water-bearing zone distinct from the water table aquifer (Shaw, 2007b). Perched water is a result of surface water infiltration impeded by the lower permeable clay below the lenses. Perched water was observed in 21 borings intersperse throughout the Plants Area of RSA-183, from as shallow as 5 feet below grade to as deep as just above the water table aquifer. The extent of the sporadic perched water is shown on Figure 5-46.

Figure 5-47 presents the potentiometric surface for the shallow unconfined, water table aquifer based on synoptic measurements collected in 2017. Historical water level statistics for each location are provided in Appendix D. As evident in Figure 5-47, groundwater highs exist north, east, and west of FA-5 that route groundwater to the groundwater trough coincident with the north-south-trending sinkhole area. In general, groundwater elevations in the lewisite manufacturing area are relatively flat with a gradient toward the south-southeast. The northeast-southwest groundwater high east of the lewisite manufacturing area, as presented on the 2014

potentiometric map (Figure 3-8) is not present on the 2017 map, suggesting this feature is transient and groundwater in the manufacturing area typically flows toward the south-southeast. A moderate gradient toward the south is evident in the sinkhole area. As discussed in Chapter 3.0, dye tracing studies and measured groundwater levels in deep wells north of FA-5 indicate that deep groundwater flows generally south toward the Huntsville Spring Branch.

#### **5.9.4 Nature and Extent of Contamination**

The current understanding of the nature and extent of contamination within FA-5 is based not only on data collected as part of the RSA-147/148/149 groundwater unit investigations but also on groundwater data collected as part of environmental investigations conducted at surface media sites RSA-049 and RSA-183. The surface media site investigations were designed in part to determine contaminant sources and evaluate their potential for impacting groundwater.

A database consisting of the most recent, usable samples collected from groundwater sampling locations within and in close proximity to FA-5 are considered representative of current conditions and used to evaluate the nature and extent of contamination within FA-5 of the RSA-147/148/149 groundwater units. The following sections describe the nature and extent of contamination in groundwater at FA-5.

**DNAPL Occurrence.** As discussed in Section 5.1, DNAPL is suspected near sampling locations where concentrations exceed 10 percent of a contaminant's solubility in water. The most recent (2013) sampling at overburden well E-RS1367, located within the lewisite manufacturing area (Figure 5-48), revealed a concentration of 11,000 µg/L. The 11,000 µg/L concentration exceeds 1 percent of CT's solubility and could reflect an elevated dissolved-phase plume surrounding a DNAPL occurrence (Table 5-1). Subsequent sampling attempts found this well to be dry. Deep well E-RS1092 was installed immediately adjacent to E-RS1367 that was screened from 93 feet to 103 feet below grade. Well E-RS1092 was found to be dry and has not been sampled. However, the boring log to this well indicates that evidence of DNAPL was found only at 51 feet below grade, described as an oily stain in a calcite infilled vug. Numerous fractures and vugs and an occasional void were present below this level and found not to contain any indication of DNAPL.

The lack of vertical migration of CT as DNAPL is supported by surrounding bedrock wells and deep bedrock wells downgradient of E-RS1367. Seven wells are screened into bedrock below the screened interval of E-RS1367 and below the deepest indication of DNAPL in the boring for well E-RS1092 (Figure 5-48). The vertical extent of DNAPL is defined in the lewisite manufacturing area to a maximum depth of 51 feet.



***Dissolved-Phase Contamination.*** In the usable FA-5 groundwater data sets that represent current conditions, six chemicals and two metals have been identified at concentrations that exceed PSVs and, in the case of metals, their BSVs as well (Table 5-11). The two metals and six chemicals are considered potential site-related contaminants to groundwater and fall within the following analytical suites:

- VOCs (five compounds)
- Explosives (one compound)
- Metals (two elements).

All site-related chemicals that exceed their PSVs are considered contaminants and evaluated in the following sections. The nature and extent of the contaminants detected in groundwater at concentrations above their PSVs were evaluated using all available information on groundwater flow regimes, including dye trace studies and other hydrogeologic evaluations discussed in Chapter 3.0, as well as distribution maps for every chemical with one or more PSV exceedances to determine lateral and vertical extents of contamination. For vertical delineation, the following discussions compare concentrations between the perched, overburden, and interface sampling zones and the bedrock sampling zone. Deep bedrock monitoring wells have not been installed within FA-5 and bedrock groundwater concentrations are suitable to confirm the vertical extent of contamination. Deep bedrock wells that are present downgradient (south) of FA-5 are used in the following discussions as supporting evidence that contaminants attributable to sites within FA-5 are not present in deep groundwater.

Analytical testing of perched water was not conducted within FA-5, though it is likely that contaminants found in water table groundwater are present in perched water. Under the most conservative scenario, the lateral extent of contamination in perched water, if present, would be defined by the lateral extent of the perched water itself, as depicted on Figure 5-46. The vertical extent of impacts to perched water would be delineated by the first occurrence of the water table groundwater.

#### ***5.9.4.1 Volatile Organic Compounds in Groundwater***

Five VOCs were detected at concentrations above their PSVs in groundwater within FA-5. In overburden groundwater, concentrations of 1,1-dichloroethene (DCE), CT, chloroform, MC, and TCE were detected above PSVs (Table 5-11). In interface wells, only TCE was detected above the PSV. The nature and extent of the VOCs exceeding a PSV in overburden and interface monitoring wells is presented in this section in decreasing order of detection frequency above their PSVs.

**TCE.** Three distinct plumes of TCE are present within FA-5 (Figure 5-49). One of the TCE plumes is present in the southern sinkhole area, one in the vicinity of the former chemical storage facility (Building 4496), and the third in the lewisite manufacturing plants area. These plumes occur in both overburden and bedrock groundwater. As evident on Figure 5-49, TCE plumes of equal or greater magnitude are present in adjacent sites MSFC-034/027 and RSA-249, which are themselves responsible for the delineation of contaminants identified in groundwater beneath them.

The shallow zone groundwater plume in the southern portion of the sinkhole area is characterized by exceedances of TCE's 5 µg/L PSV in wells E-RS1083 at 7.97 µg/L and F-RS1145 at 26 µg/L (Figure 5-49). The lateral extent of elevated TCE in the shallow flow zone is defined downgradient to the south by well F-RS1135 (nondetect), E-RS1372 (1.6 µg/L), and F-RS1067 (nondetect); upgradient to the west by wells E-RS1077 (nondetect); upgradient to the north by well E-RS1371 (2.13 µg/L); and upgradient to the east by well F55-RS1067 (nondetect). The lateral extent of this TCE plume in the shallow flow zone is defined to below the PSV.

TCE has impacted an appreciable area of the northern portion of FA-5 (Figure 5-50). A relatively small shallow zone plume of TCE above the PSV encompasses wells E49-RS263 (7.07 µg/L) and E-RS1367 (83 µg/L). This localized plume is laterally defined by well E-RS1368 (0.44 µg/L) to the south, well E-RS1365 (2.02 µg/L) to the west, wells F49-RS1592 (1.65 µg/L) and E49-RS638 (0.474 µg/L) to the north, and well E-RS1364 (0.49 µg/L) to the east. The two overburden PSV exceedances were found in wells within the footprint of former lewisite Plant #2 and in close proximity to the former industrial sewer line. Releases of TCE within lewisite Plant #2 are the likely source for the PSV exceedances observed in these two overburden wells.

A TCE plume is associated with the former chemical storage facility at Building 4496 (Figure 5-50) that is centered near overburden wells E-RS1081 (270 µg/L) and E-RS1080 (150 µg/L) and interface well 148-RS2512 (162 µg/L). This plume is defined in the shallow groundwater zone to the south by well E-RS1133 (0.72 µg/L), upgradient to the east by piezometer MC-PZDY-001 (nondetect), and cross gradient/upgradient to the north by E183-HP15 (nondetect) and 148-RS1973 (0.59 J µg/L). The downgradient extent of this plume to the east-southeast is defined by E-RS1134 (nondetect) and 249-RS2308 (nondetect) and to the south by E-RS1098 (3.15 µg/L) and several DPT locations (Figure 5-49). Releases of VOCs (specifically TCE) at the former chemical storage facility have not been documented. However, the shallow nature, extent, and configuration of this overburden plume strongly suggest a source in the vicinity of the former chemical storage facility.

As shown on Figure 5-49, a fairly large TCE plume is present in the MSFC-027/034 area. The extent and concentration of TCE (up to 32,900 µg/L) are much greater than those found within FA-5. This MSFC plume is generally situated upgradient of FA-5 and extends into shallow overburden in the western portion of FA-5.

Four TCE plumes are present within the shallow flow zone in FA-5. Two TCE plumes appear to have been the result of releases within FA-5: the localized plume in the northern portion of the lewisite manufacturing area and one at Building 4496. The overburden and shallow bedrock plume in the sinkhole area is attributed to RSA-249. Similarly, TCE present in overburden wells in the western portion of the lewisite manufacturing area is the downgradient leading edge of the TCE plume emanating from MSFC-034/027.

There are currently no deep bedrock wells within FA-5. However, TCE was not detected or detected below the PSV in most recent samples from several deep flow zone wells surrounding the FA-5 area, including MC-MW00-403Db and T-RS1144 to the west and 249-RS2866 and F54-RS302 to the east. An analytical summary for deep flow zone monitoring wells in the vicinity of FA-5 is presented as Table 5-12; well locations are shown on Figure 5-51. TCE was detected above the PSV in a deep well to the south (22 µg/L in F10-RS545); however, F10-RS545 is associated with and the responsibility of surface media site RSA-010.

**CT.** The extent of CT in FA-5 is shown on Figure 5-52. As evident on that figure, CT in excess of the 5 µg/L PSV within FA-5 is present only in the lewisite manufacturing area. A CT plume with concentrations up to 129,000 µg/L (well MC-MW00-404) is present in the MSFC area to the west of FA-5, but it appears that the MSFC CT plume does not impact shallow groundwater in FA-5. A distinct CT plume is also present just north of FA-5 along the southern boundary of RSA-049. This plume is not attributed to FA-5 as it is within and downgradient of the former arsenic waste lagoon at RSA-049 that received waste liquids from the lewisite manufacturing plants.

CT was used in the lewisite site for decontamination and Shaw (2007b) identified the likely source of CT in shallow groundwater as the sumps and collection pits of the former plants. The CT plume within FA-5 is centered at the former collection pit at lewisite Plant #2 at 11,000 µg/L reflected in well E-RS1367, with a second area of elevated CT centered at the collection pit and sump of lewisite Plant #1 reflected in well E-RS1070 at 540 µg/L (Figure 5-53). Within the lewisite manufacturing area, only overburden wells exhibit PSV exceedances for CT. The extent of CT above the PSV is defined in overburden by numerous wells within the manufacturing area (Figure 5-53).

The CT PSV exceedances are all found in overburden wells screened to a depth of less than 40 feet below grade. However, the boring advanced into bedrock adjacent to well E-RS1367 suggested possible DNAPL at a depth of 50 feet below grade. The vertical extent of CT below the PSV is evaluated using bedrock wells screened below 50 feet of grade.

The lateral and vertical extent of CT is defined based on results from bedrock wells screened below 50 feet that surround the FA-5 CT plume (Figure 5-53). Bedrock well E-RS1097 is located less than 50 feet from the E-RS1070 and screened from 85.75 to 95.75 feet below grade. Recent results from this well did not detect CT, indicating elevated CT did not migrate into bedrock at this location. To the south, wells E-RS2254 (screened from 53.7 to 68.7 feet) and E-RS1096 (screened from 97 to 106.75 feet) both did not show detectable CT. To the east, bedrock wells E-RS1094 (screened from 83 to 92.75 feet) and F-RS1593 (screened from 107 to 117 feet) showed no detectable CT or were below the PSV for CT. To the west, bedrock well E-RS1074 (screened from 95.75 feet to 105.75 feet) exhibited no detectable CT. To the north, adjacent to the CT plume associated with RSA-049, bedrock wells F49-RS1591 (screened from 51 to 66 feet) and F49-RS1590 (screened from 69 to 79 feet) also failed to detect CT. Collectively, these results indicate that the CT plume within FA-5 is defined to below the PSV in shallow bedrock groundwater. CT was not detected or detected below the PSV in deep flow zone monitoring wells that surround FA-5 (Table 5-12; Figure 5-51).

The primary sources of CT present in the northern portion of FA-5 were likely the collecting pits and sumps of Plants #1 and #2 (Shaw, 2007b). The current extent of CT in groundwater in FA-5 is consistent with this contention. The greatest concentration of CT was associated with Plant #2 in the same well that historically showed 110,000 µg/L, suggesting possible DNAPL. CT concentrations above the PSV from plumes in the MSFC to the west and RSA-049 to the north do not appear to extend into FA-5.

**Chloroform.** Concentrations of chloroform above the PSV were detected at two isolated locations within FA-5, both of which were located in the vicinity of the former lewisite manufacturing area in the northern portion of FA-5 (Figure 5-54). A detail of the northern portion of FA-5 is presented on Figure 5-55 that shows well E-RS1076 contained 86 µg/L and well E-RS1367 contained 660 µg/L. Well E-RS1076 was installed in close proximity to a collecting pit and sump of Plant #1, and well E-RS1367 was installed in close proximity to a collecting pit and sump of Plant #2.

The lateral and vertical extent of chloroform at these two locations is defined to below the PSV (Figure 5-55). The lateral extent of the PSV exceedance found at well E-RS1367 is defined to the south by well E-RS1368 (2.8 µg/L), to the west by E-RS1365 (0.77 µg/L), to the north by E49-

RS263 (0.664 µg/L), and to the east by E-RS1364 (0.51 µg/L). Similarly, the PSV exceedance at E-RS1076 is laterally defined to below the PSV by DPT locations MC-GP04-446 (nondetect) and MC-GP04-431 (nondetect), to the west by DPT location E183-HP08 (nondetect), to the north by well E-RS1362 (0.84 µg/L), and to the east by well E-RS1363 (0.41 µg/L). Deeper within bedrock, the vertical extent of chloroform above the PSV within the lewisite manufacturing area is defined to the south by well E-RS1096 (nondetect) and 148-RS2254 (nondetect), to the west by wells E-RS1094 (nondetect) and F49-RS1593 (nondetect), to the north by wells E-RS1090 (nondetect) and F49-RS1591 (0.271 µg/L), and to the east by E-RS1074 (0.295 µg/L). Chloroform was not detected or detected below the PSV in deep flow zone monitoring wells that surround FA-5 (Table 5-12; Figure 5-51). The vertical extent of chloroform contamination is also confirmed by bedrock well E-RS1093, located in close proximity to the PSV exceedance in well E-RS1096, which did not contain detectable chloroform.

The fact that the two PSV exceedances of chloroform in groundwater were associated with the former lewisite plants and subsurface soil also contained PRG exceedances for chloroform (Shaw, 2007b) strongly suggests that releases of chloroform were associated with the lewisite manufacturing site. However, chloroform was not reported as used in the manufacturing process (Shaw, 2007b). The presence of chloroform in shallow groundwater in FA-5 is likely a result of degradation of CT (Appendix I). The source of chloroform by degradation of CT is supported by the fact that the only two exceedances of chloroform were found in the two wells that exhibited the greatest concentrations of CT (wells E-RS1367 and E-RS1076). The lateral and vertical extent of chloroform above the PSV is defined in FA-5.

**1,1-Dichloroethene.** Concentrations of 1,1-DCE were detected at five monitoring well locations, all of which were located in the vicinity of the former lewisite manufacturing area in the northern portion of FA-5 (Figure 5-56). However, only two of the detections were above the PSV. A detail of the northern portion of FA-5 is presented on Figure 5-57 that shows the locations of the two wells exhibiting a PSV exceedance (E-RS262 at 13.9 µg/L and E-RS1081 at 77 µg/L). Neither of these wells is in the immediate footprint of the former lewisite plants.

The lateral extent of 1,1-DCE in FA-5 is defined by wells that do not show PSV exceedances (Figure 5-57). The exceedance at well E49-RS263 is defined to the south by wells E-RS1364 (nondetect) and E-RS1367 (0.44 µg/L), to the west by DPT locations E183-HP01 (nondetect) and E-HP18 (nondetect), and well E-RS1365 (nondetect); to the north by wells E49-054 (nondetect) and E-RS1592 (nondetect), and to the east by DPT location E-HP12 (nondetect). The PSV exceedance at well E-RS1081 is laterally bounded to south by well 148-RS2514

(nondetect), to the west by well 148-RS2513 (3.46 µg/L), to the north by DPT location E183-HP13 (nondetect), and to the east by DPT location 14801E-HP01 (nondetect).

1,1-DCE was not detected or detected below the PSV in deep flow zone monitoring wells that surround FA-5 (Table 5-12; Figure 5-51). The vertical extent of chloroform contamination is further confirmed by the lack of PSV exceedances in bedrock wells in close proximity to the plume including well E-RS1097 (nondetect) to the south; wells E-RS1094 (nondetect), E-RS1093 (nondetect), and F49-RS1593 (nondetect) to the west; wells E-RS1090 (nondetect) and F49-RS1591 (nondetect) to the north; and wells E-RS1074 and E-RS1096 to the east.

The 1,1-DCE observed in FA-5 likely results from degradation of other chlorinated compounds (Appendix I). The extent of the 1,1-DCE contaminant plume is a subset of the TCE, and no documentation has suggested that TCE was involved in the lewisite manufacturing process (Shaw, 2007b).

**Methylene Chloride.** MC was detected above the PSV at only one location within FA-5 (Figure 5-58). The PSV exceedance was located in the lewisite manufacturing area in the northern portion of FA-5, within the footprint of the lewisite Plant #1.

The lateral and vertical extent of MC above the PSV is defined (Figure 5-59). The lateral extent of the PSV exceedance at well E-RS1076 (23 µg/L) is defined to the south by well E-RS1370 (nondetect), to the west by DPT locations E183-HP07 (nondetect) and E183-HP08 (nondetect), to the north by well E-RS1362 (nondetect), and to the east by well E-RS1362 (nondetect). Bedrock wells E-RS1096 (nondetect) to the southeast, E-RS1094 (nondetect) to the southwest, F49-RS1593 (nondetect) to the north, and wells F49-RS1591 (nondetect) and 148-RS2254 (nondetect) to the east define the vertical extent of MC above the PSV in bedrock. Vertical delineation is also confirmed in the fact that MC was not detected or was detected below the PSV in deep flow zone monitoring wells surrounding FA-5 (Table 5-12; Figure 5-51).

MC was detected above the PSV at one location coincident with the former lewisite Plant #1. MC was not reported as having been used in the lewisite manufacturing process (Shaw, 2007b). Similar to chloroform, the presence of MC in shallow groundwater in FA-5 is likely a result of degradation of CT (Appendix I). Again as with chloroform, the only PSV exceedance of MC was observed at a well that also contained elevated CT (well E-RS1367). The single PSV exceedance of MC in FA-5 is associated with degradation of CT and is defined laterally and vertically to below the PSV.

#### **5.9.4.2 Explosive Compounds in Groundwater**

**Nitrobenzene.** Nitrobenzene was detected above the PSV in two wells within FA-5 (Figure 5-60). Both of these wells are located in the sinkhole area of FA-5 with bedrock well E-RS1140 containing 0.235 µg/L and overburden well E-RS1371 containing 0.41 µg/L. There are no documented sources of nitrobenzene within FA-5 (Shaw, 2007b). The lateral extent of nitrobenzene in FA-5 is generally defined to the south by well F74-RS565 (nondetect); to the east by wells MC-MW00505 (nondetect) and T141-RS1146 (nondetect); to the north by 249-RS2308 (nondetect); and to the east by wells E-RS1083 (nondetect), F54-RS304 (nondetect), and F54-RS385 (nondetect).

The extent of nitrobenzene in overburden and bedrock is defined to below the PSV. Nitrobenzene was not detected in deep bedrock well F54-RS301, located east of FA-5 (Table 5-12; Figure 5-51).

#### **5.9.4.3 Metals in Groundwater**

Metals are detected in groundwater at concentrations exceeding their PSVs and BSVs; however, as explained in Section 5.2, metals also exist as natural constituents of soil and groundwater. Therefore, metals concentrations in these media were evaluated using statistical and geochemical methods to determine whether a particular metal concentration is naturally occurring or is potential site-related contamination. The nature and extent evaluation portrays current conditions and utilizes the most recent analytical result from each location for each parameter.

Metals concentrations are considered to be contamination only if the concentration exceeds the PSV and BSV and are identified in the site-to-background evaluation as anomalous. Table 5-3 lists those locations where metals in most recent samples were detected at concentrations exceeding PSVs and BSVs and identified as statistically and geochemically anomalous.

From examination of Table 5-3, specific concentrations of arsenic and mercury are the only metals detected within FA-5 with concentrations that exceed both their PSV and BSV and were identified by the site-to-background evaluation as anomalous.

**Arsenic.** Arsenic entered the environment at the lewisite manufacturing site as a result of inadvertent releases and process discharges that were routed to the capped arsenic waste disposal pond. Surface and subsurface releases of arsenic migrated through the soil column to impact groundwater. Arsenic in three shallow overburden wells (E-RS1363, E-RS1368, and F49-RS1592) exceeds the 10 µg/L PSV and 5.1 µg/L BSV, as shown on Figure 5-61. These three wells are separated by wells that contain arsenic below the PVS, indicating that the lateral extent of elevated arsenic is localized within the saturated overburden. The greatest concentration of

arsenic was found at well E-RS1368 at 340 µg/L. This exceedance is laterally defined by well E-RS1369 (8.2 µg/L) to the south, E-RS1366 (4.2 µg/L) to the west, 148-RS2511 (nondetect) to the east, and E-RS1367 (9.8 µg/L) and E-RS1364 (nondetect) to the north. Well E-RS1363 contained 60 µg/L arsenic and this PSV exceedance is defined by well E-RS1370 (2.0 µg/L) to the south, E-RS1093 (nondetect) to the west, E-RS1362 (nondetect) to the north, and E-RS1366 (4.2 µg/L) to the east.

Well F49-RS1592 is located on the downgradient southern border of the capped arsenic waste disposal pond of RSA-049 and contained 11.8 µg/L arsenic. Wells E-RS263, E-RS1364, and 148-RS2511 are located between RSA-049 and FA-5 and these three wells each showed no detectable arsenic. The elevated arsenic found in well F49-RS1592 is attributed to releases from the arsenic waste disposal pond and not the lewisite manufacturing plants area of FA-5.

Arsenic was not detected in bedrock wells located near exceedances in overburden groundwater. Figure 5-61 shows bedrock well locations (yellow highlights) that surround the three arsenic exceedances in overburden wells. Bedrock wells 148-RS2254 and E-RS1096 are downgradient of the overburden PSV exceedance wells, and arsenic was not detected in these two bedrock wells. Arsenic in bedrock is defined to the west by wells E-RS1093 (nondetect) and F49-RS1593 (nondetect). Well E-RS1090 (nondetect) defines elevated arsenic in bedrock to the north. Bedrock wells F49-RS1590 (nondetect), E-RS1074 (nondetect), and 148-RS2254 (nondetect) define arsenic in bedrock groundwater to the east. Interestingly, bedrock well E-RS1093 showed no detectable arsenic, and this well is located about 50 feet from PSV exceedance in overburden well E-RS1363. The lack of detection in bedrock groundwater adjacent to elevated arsenic in overburden confirms the vertical delineation of arsenic in overburden groundwater.

Surface and subsurface releases of arsenic from the manufacturing processes at the lewisite plants in RSA-183 have impacted soil and shallow groundwater (Shaw, 2007b). Two arsenic PSV exceedances are observed in overburden groundwater within the footprints of the lewisite manufacturing plant sites. The arsenic exceedance in well F49-1592 is adjacent to, and downgradient of, the arsenic waste disposal pond which is the likely source of the arsenic in groundwater in this area. The lateral extent of elevated arsenic at FA-5 is defined to below the PSV by numerous overburden wells that surround the exceedances. Similarly, numerous bedrock wells surrounding the PSV exceedances define the vertical extent of arsenic above the PSV.

**Mercury.** Mercury has impacted soil and groundwater at the former lewisite manufacturing site as a result of inadvertent releases and process discharges that were routed to the capped arsenic waste disposal pond (Shaw, 2007b). Surface and subsurface releases of mercury migrated through the soil column to impact groundwater. Overburden well E-RS1363 was found to



contain 9.9 µg/L mercury that exceeded the 2 µg/L PSV and 0.2 µg/L BSV (Figure 5-62). The single PSV exceedance is laterally bounded in overburden by well E-RS1370 (0.08 µg/L) to the south, E-RS1076 (0.25 µg/L) to the west, E-RS1362 (nondetect) to the north, and E-RS1365 (nondetect) and E-RS1366 (0.09 µg/L) to the east. Bedrock wells 148-RS2254 (southeast), E-RS1094 (southwest) F49-RS1593 (northwest), E-RS1090 (north), F49-1591 (northeast), and E-RS1074 (east) all show no detectable mercury and bound the vertical extent of mercury exceedances found in overburden well E-RS1363.

The single PSV exceedance of mercury in overburden well E-RS1363 is beneath the footprint of former lewisite Plant #1, which was the likely source of this contaminant. The PSV exceedance is bounded laterally and vertically by wells that are below the PSV. A PSV exceedance of mercury at 14.6 9.9 µg/L was found in well E27-RS850 (Figure 5-62), but this well is located upgradient in MSFC-027 that has documented releases of mercury to groundwater (CB&I, 2015b). The exceedance of mercury at E27-RS850 is not attributed to FA-5.

#### **5.9.5 Summary and Conclusions**

Groundwater at FA-5 is impacted with metals, explosives, and VOCs. Arsenic and mercury were associated with the lewisite manufacturing process and have impacted both soil and groundwater. The groundwater impact above the PSVs from arsenic and mercury is restricted to overburden groundwater, and the extent of arsenic and mercury in groundwater is defined to below the PSVs. Nitrobenzene was the only explosive found above the PSV within FA-5. The source of nitrobenzene within FA-5 is not known, but the lateral extent of nitrobenzene above the PSV in the shallow flow zone is defined to below the PSV, and the downgradient extent in deep bedrock is also defined.

The VOCs 1,1-DCE, CT, chloroform, MC, and TCE are found above their PSVs in groundwater beneath FA-5. The extent of these VOCs is defined laterally in the shallow flow zone and vertically in deep bedrock to below the PSV. The sources of 1,1-DCE, CT, chloroform, and MC are associated with operations with RSA-183 or degradation products from VOC released within RSA-183. TCE was released within FA-5 from historical operations conducted at RSA-183, but TCE from sources outside of FA-5 have contributed to groundwater impact within FA-5. Sources of groundwater impact at FA-5 are summarized below.

			Unit or Site Responsible for Addressing Groundwater COCs/COACs	
Focus Area	SWMUs	Relevant Groundwater COCs/COACs	Delineation	Remedy
FA-6	RSA-183	TCE	RSA-183, MSFC-027/034, RSA-249	RSA-149
		Arsenic		
		Nitrobenzene	RSA-149	
		1,1-Dichloroethene	RSA-183	
		CT		
		Chloroform		
		MC		
Mercury				

### 5.10 Focus Area 6

FA-6 is located on the northwest corner of the Rideout Road and Pioneer Street intersection (Figure 5-63). The site encompasses the area of the northern portion of Building 4722 (formerly Buildings 421 and 422).

#### 5.10.1 Site Description and History

Buildings 421 and 422 were constructed in 1943 for materials storage. Former Building 421 is the northernmost structure, while former Building 422 is the southernmost structure. Currently, Building 4722 is used for administrative services.

Historical records were reviewed to evaluate potential sources of contaminants at Building 4722 (Shaw, 2005b). Initially, historical documentation indicated that Building 421 was used for storage of gas masks, safety goggles, respirators, gloves, safety and impregnated shoes, personal protective equipment, and office equipment. Building 422 was used for storage of compressed gases, empty gas cylinders, and supplies for use in lewisite manufacturing Plant No. 1, located in RSA-183. Stored containers included drums, acid carboys, and repair materials for the chlorine and caustics plants. These activities were conducted from 1943 until approximately 1954. Building utilization in 1954 indicates that Building 421 was the guided missile division headquarters as well as a structures and mechanics laboratory, while Building 422 was primarily devoted to a structures and mechanics laboratory.

In 1957, Building 4722 was designated as office and laboratory, while 1959 documents indicated that Building 4722 was the Chrysler Corporation Engineering Service Center (Shaw, 2005b). The 1968 building use index again indicates usage as office and laboratory. The 1991 designation for building use was that of an “ADP” facility, with recent usage being termed administrative.

In addition to the previously described activities, ancillary activities appear to have been conducted at Building 4722 (Shaw, 2005b). These additional activities included black and white photographic and microfilm processing with waste being discharged to the sanitary sewer. A jig borer was reportedly installed in 1961 for precision vertical drilling, boring, and milling operations. X-ray units, tanks, and vats were reportedly to have been installed in 1951, but their function is not reported. Engineering drawing for former Building 422 indicated plans for a rubber and plastics laboratory. Lastly, a propulsion research laboratory for guidance missiles was housed in the northern portion of Building 4722.

Review of operations conducted at Building 4722 indicates that it was primarily used for storage or administrative/office activities. Contaminants such as VOCs or metals do not appear to have been routinely used in the building.

***Investigative History.*** An LSA was conducted at 149-PE-01A (Building 4722) to evaluate environmental conditions at the potential site (Shaw, 2005b). This study collected and tested soil and groundwater samples for VOCs from five direct-push borings that were located in areas suspected of potential impact that included the former loading dock, adjacent to the chemical storage areas, exposed drainage piping, and drainage areas where discharge from the building was suspected (Figure 5-63). Analytical results from three soil samples from each of the five borings did not detect TCE; however, TCE was detected at a concentration of 600 µg/L in 14901A-HP03, located along the northwestern portion of Building 4722. TCE was not detected in the two groundwater samples from the southwestern portion of the building.

### **5.10.2 Hydrogeology**

Regionally, groundwater occurs in both the unconsolidated overburden and bedrock at RSA. In the area that includes FA-6, the potentiometric surface indicates a dominantly west-northwest direction of flow for shallow groundwater (Figure 5-64). However, historical groundwater elevation data indicate FA-6 is located just west of a northeast-southwest-trending groundwater high that directs flow both westward and southward, suggesting groundwater flow varies in the vicinity of FA-6.

### **5.10.3 Nature and Extent of Groundwater Contamination**

The usable FA-6 groundwater data sets that represent current conditions consists of one sample analyzed for VOCs. In this data set, only TCE was identified at concentrations that exceeded a PSV. TCE was, in fact, the only VOC detected (Table 5-13).

Impacted groundwater at FA-6 is identified by one well (149-RS1986). TCE was detected in this well at a concentration of 7.13 µg/L, which exceeds the 5 µg/L PSV (Figure 5-64). This

overburden well was installed adjacent to hydropunch 14901A-HP03, where TCE was detected at a concentration of 600 µg/L during the site assessment (Shaw, 2005). Few wells exist in the area of FA-6, because this area was not identified as a major source for groundwater contamination. Sampling of other hydropunch locations at this site (14901A-HP05 and 14901A-HP06) did not indicated detectable TCE and these locations defined the extent of TCE contamination cross gradient to the south. TCE was not detected in upgradient wells TD-RS761, TD-RS762, and TD-RS763, located east of FA-6. TCE was also not detected in cross-gradient well MC-MWBK-002, located north of FA-6. Two wells (U72-RS1342 and U72-RS1344) are located approximately 2,500 feet downgradient of FA-6, and TCE was not detected in the most recent sampling of these wells.

The extent of TCE within FA-6 in groundwater is presented on Figure 5-64. TCE concentrations are bounded by wells or piezometer samples where TCE was not detected. The relatively restricted areal extent of elevated TCE shown on Figure 5-64 is based on the very slight PSV exceedance that characterizes this location. TCE does not exceed the PSV in deep flow zone monitoring wells located south (downgradient) of FA-6, as shown on Figure 5-65. An analytical summary of TCE concentrations in deep bedrock is presented as Table 5-14. The absence of an identifiable source for the TCE detected at FA-6 and the fact that well 149-RS1986 exhibits a TCE exceedance just slightly over the PSV confirm the lateral and vertical extent of TCE concentrations are defined.

The Army's plan for addressing the TCE at FA-6 is presented below.

Focus Area	SWMUs	Relevant Groundwater COCs/COACs	Unit or Site Responsible for Addressing Groundwater COCs/COACs	
			Delineation	Remedy
RSA-149	None (Bldg. 4722)	TCE	RSA-149	RSA-149

### **5.11 Nature and Extent Summary and Conclusions**

The current understanding of the nature and extent of contamination within RSA-147/148/149 is based not only on data collected as part of the groundwater unit investigations but also on groundwater data collected as part of environmental investigations conducted at the surface media sites that lie within the RSA-147/148/149 boundaries. VOCs, SVOCs, explosive compounds, pesticides, and PCBs have been identified in groundwater and surface water within the RSA-147/148/149 groundwater units at concentrations above PSVs. Many of these exceedances are associated with surface media sites, and the responsibility of delineating their

extent lies with those surface media sites. The RSA-147/148/149 groundwater units are responsible for delineating contaminants identified at locations that are no longer being investigated by surface media sites or are otherwise “outlier” locations not associated with a surface media site. The vast majority of these locations are grouped within six FAs.

In most recent groundwater samples collected within the six FAs and outlier locations, 11 VOCs, 5 SVOCs, 5 pesticides, 10 explosive compounds, and 3 metals were detected at concentrations above their PSVs. CBZ at FA-4 and, to a lesser extent, CT at FA-5 have also been found at concentrations that suggest the possibility of DNAPL. Anomalous metals concentrations were also detected in FA-2 and FA-5 groundwater samples but are generally localized within those FAs.

Certain dissolved-phase contaminants within the groundwater FAs form plumes of limited extent within the overburden and shallow bedrock groundwater (shallow flow zone). No exceedances associated with these FAs were detected in the deep flow zone. Exceedances identified in outlier locations are isolated concentrations that do not form plumes. The FA plumes and outlier exceedances are summarized below.

#### **5.11.1 Outlier Locations**

A total of 83 monitoring wells and 1 spring location lie outside FA boundaries but are the responsibility of the groundwater units. Concentrations within the vast majority of these sampling locations do not exceed a PSV. However, a concentration of one SVOC in one outlier monitoring well does exceed the PSV.

One SVOC, benzo(a)anthracene, was identified in the overburden well H62-RS045 located southwest of RSA-061/062 (Figure 5-3). The lateral and vertical extent of this exceedance are defined by locations where this SVOC was not detected or detected below the PSV. Defining locations include H109-RS1104 and 109-RS2779 to the west; 148-RS1976, spring MC-IXMLSS, and bedrock multizone well 148-RS1978 to the east; and Huntsville Spring Branch to the south. Location associated with RSA-061/062 to the north and northeast include locations where benzo(a)anthracene exceeds the PSV and is the source of the exceedance detected in H62-RS045.

The lateral and vertical extent of the PSV exceedance identified in outlier sampling locations for which the RSA-147/148/149 groundwater units are responsible is delineated.

#### **5.11.2 Focus Area 1**

FA-1 encompasses the RSA-057 surface media site and includes the area of two former sludge ponds built to treat and contain liquid wastes from the lewisite production process (Figure 5-4).

Corrective measures performed 2008 successfully removed soils contaminated with arsenic and mercury. In the most recent, usable groundwater samples analyzed for VOCs, SVOCs, pesticides/PCBs, explosives, and metals at FA-1, TCE was the only compound detected in groundwater at concentrations that exceed a PSV. The elevated TCE concentrations are attributed to the waste stream disposed of in the former waste ponds.

TCE is present in 12 of the 21 samples collected in and around FA-1, but PSV exceedances were observed in only three shallow zone monitoring wells. The resulting TCE plume encompasses much of the FA-1 site and extends into the surrounding area, but is completely bounded in downgradient, cross-gradient, and upgradient directions by sampling locations where TCE was not detected or detected below the PSV (Figure 5-6). Vertical migration of TCE is not occurring at RSA-057, as confirmed in most recent samples from deep flow zone monitoring wells Z-RS1230D to the north, Z-RS1236D to the south, and F122-RS513 to the west. All concentrations of TCE that exceed its PSV are delineated, both laterally and vertically at FA-1.

### **5.11.3 Focus Area 2**

FA-2 encompasses the RSA-122 surface media site and includes several sites that lie within and adjacent to the RSA-122 boundary (Figure 5-8). The site includes four former lewisite production plants, sulfur monochloride and AT production plants, two former waste ponds (RSA-056 and RSA-139), and other production support facilities. Corrective measures performed in 2011 removed soils contaminated with arsenic and mercury from historic use of the site to produce the arsenic-based lewisite. In the 62 most recent, usable groundwater samples analyzed for VOCs, SVOCs, pesticides/PCBs, explosives, and metals at FA-2, concentrations of four VOCs and five SVOCs were detected at concentrations that exceed their PSV. Concentrations of arsenic and mercury were also detected exceeding both their PSV and BSV. Contaminants are attributed to the historical operation of the site for lewisite production.

TCE is the most common VOC detected in the shallow flow zone, although no mappable plume pattern is evident that would suggest site soils serve as a continuing source for groundwater contamination. Other contaminants detected in shallow groundwater include PCE, 1,1,2,2-TeCA, and bromomethane. Likewise, these other VOC contaminants form no discernable plume patterns. All sampling locations where a VOC exceeds its PSV are surrounded in downgradient, cross-gradient, and upgradient directions by sampling locations where the most recent analytical data indicate those contaminants are not detected or detected below their PSV (Figure 5-10).

Of the five SVOCs, bis(2-ethylhexyl)phthalate is the most commonly detected compound. Six locations, four of which are screened in perched groundwater, exceed the PSV. Other SVOCs that exceed their PSVs in shallow groundwater, but form no plume areas, include

benzo(a)anthracene, dibenz(a,h)anthracene, benzo(a)pyrene, and naphthalene. All sampling locations where a SVOC exceeds its PSV are surrounded downgradient, cross-gradient, and upgradient sampling locations where those compounds are not detected or detected below their PSV in most recent samples (Figure 5-11).

Arsenic and mercury were also detected at concentrations that exceed both their PSV and BSV and were evaluated in the site-to-background evaluation as possible site-related contamination, indicating that mobilization of those contaminants identified in soil has occurred. However, all concentrations of both arsenic and mercury above their screening values and identified as anomalous are delineated by samples below a screening value or determined to be most likely a natural component of groundwater (Figures 5-12 [arsenic] and 5-13 [mercury]).

All concentrations of VOC, SVOC, and metals contaminants identified at FA-2 in most recent groundwater samples are delineated, both laterally and vertically.

#### **5.11.4 Focus Area 3**

FA-3 includes the area surrounding former Building 5413, a building historically used as a control analytical laboratory for ordnance inspection (Figure 5-14). Three VOCs (TCE, CT, and 1,1,2,2-TeCA) have been identified at FA-3 at concentrations above PSVs; all were single detections in shallow zone monitoring well 147-RS1972. It is unlikely that the historical operations at Building 5413 have resulted in these VOCs in groundwater; historical migration of VOC plumes from upgradient (west-southwest) are the more likely source of VOCs detected in 147-RS1972. Laterally, VOC exceedances identified in this monitoring well are completely bounded in all directions by wells in which VOCs were either not detected or detected below the PSVs. The vertical extent of contaminants identified in the shallow flow zone at FA-3 is defined by locations surrounding FA-3 that monitor the deep flow zone.

#### **5.11.5 Focus Area 4**

FA-4 encompasses portions of three surface media sites: the western portion of RSA-053, the southernmost portion of RSA-183, and the eastern portion of RSA-010 (Figure 5-20). In groundwater samples that are the responsibility of the RSA-147/148/149 groundwater units, PSV exceedances in the most recent groundwater data include 9 VOCs, 6 pesticides, and 10 explosives. Other exceedances exist within the FA-4 area, but responsibility for these exceedances is consigned to the surface media sites.

One VOC was detected at a concentration indicative of potential DNAPL. CBZ was detected in monitoring well 053-RS2004 at a concentration that exceeds 10 percent of its solubility, indicating a potential for the presence of DNAPL (Figure 5-25). A broader halo exceeding

1 percent of the solubility of CBZ in the shallow groundwater zone reflects the elevated dissolved-phase plume surrounding the DNAPL location.

VOC, pesticide, and explosive contaminants at FA-4 were released to the environment as part of the disposal of wastes in the NDA of RSA-053. One anomalous manganese detection is also present in FA-4 groundwater. TCE and 1,1,2,2-TeCA are the most widespread exceedances creating the most laterally collocated extensive plumes commingled with RSA-010 plumes (Figures 5-28 [TCE] and 5-32 [1,1,2,2-TeCA]). The plumes lie within the groundwater flowpaths of dye detection associated with upgradient sources. The responsibility for groundwater action for TCE and 1,1,2,2-TeCA in shallow groundwater zone in this area has been assumed by RSA-010.

Plume areas created by other VOC contaminants (CBZ, chloroform, MC, and benzene) are of much more limited extent and are confined to the RSA-053 NDA (Figures 5-26 [CBZ], 5-29 [chloroform], and 5-30 [MC], and 5-31 [benzene]). As shown on those figures, all VOC contaminants are delineated in the shallow flow zone by well locations where concentrations are below the PSV or are not detected.

Of the 10 explosive compounds detected in shallow zone groundwater exceeding their PSV, most occur in one or two sampling locations (Figure 5-35). Only 2-NT concentrations form a plume (Figure 5-34). The 2-NT plume originates from RSA-010, extending into FA-4 and spanning the shallow zone groundwater at both RSA-010 and RSA-053. RSA-010 has assumed responsibility for the 2-NT in groundwater in this area. All shallow groundwater flow zone explosive compounds contaminants are bounded on all sides with sample locations that did not contain detectable compounds or that showed a detected concentration below the PSV.

Six pesticides were detected in shallow zone groundwater above their PSVs. Four of the pesticides are clustered and localized within the NDA (Figures 5-36 [beta-BHC], 5-37 [dieldrin], 5-38 [4,4'-DDE], and 5-39 [4,4'-DDD]). Aldrin and beta-BHC plumes extend beyond FA-4, commingling with plumes within RSA-010. However, all pesticide exceedances in shallow zone groundwater are delineated by locations where they were found to be below PSVs or were not detected.

No contaminants were detected in the deep zone samples at FA-4, confirming vertical delineation of all contaminants identified in the shallow zone samples. Both the lateral and vertical extent of groundwater contamination in FA-4 are completely delineated.



An LTM program is being implemented and LUCs are in place for RSA-053, including the NDA where most of the contaminants were detected. A compliance monitoring program and LUCs are also in place at RSA-010.

#### **5.11.6 Focus Area 5**

FA-5 encompasses the northern and central portions of RSA-183, including the former lewisite manufacturing operations area and extending southward to include a large sinkhole drainage area (Figure 5-43). Contaminants identified in shallow zone groundwater at FA-5 include five VOCs (1,1-DCE, CT, chloroform, MC, and TCE), one explosive (nitrobenzene), and two metals (arsenic and mercury). Contaminants are present as a result of historical operations at facilities within FA-4, including production and waste processing of the arsenic-based lewisite and related materials.

Of the five VOC contaminants, only CT was identified at concentrations that could indicate the presence of DNAPL. A concentration that was at CT's 1 percent solubility concentration was detected in most recent sampling at one overburden monitoring well (E-RS1367), which could reflect an elevated dissolved-phase plume surrounding a DNAPL occurrence (Figure 5-48).

The extent of all five VOCs is defined to concentrations below the PSV both laterally, in the shallow flow zone, and vertically, in deep bedrock groundwater. The sources of 1,1-DCE, CT, chloroform, and MC are associated with operations with RSA-183 or degradation products from VOC releases within RSA-183. TCE was released within FA-5 from historic operations conducted at RSA-183, but TCE from sources outside of FA-5 have contributed to groundwater impact within FA-5.

Nitrobenzene was the only explosive found above the PSV within FA-5. The source of nitrobenzene within FA-5 is not known, but the lateral extent of nitrobenzene above the PSV in shallow groundwater is defined to below the PSV, and the downgradient extent in deep bedrock is also defined.

Arsenic and mercury at concentrations that exceed both their PSV and BSV were identified in the site-to-background analysis as anomalous, indicating site-related contamination. The groundwater impact from arsenic and mercury is restricted to shallow overburden wells and the extent of these metals in groundwater is defined by surrounding sampling locations that are below PSVs and/or BSVs.

#### **5.11.7 Focus Area 6**

FA-6 encompasses the area of the northern portion of Building 4722 (Figure 5-63). These buildings have had multiple uses through the years including storage of compressed gases, empty

gas cylinders, drums, acid carboys and repair materials for the chlorine and caustics plants, and supplies for use in lewisite manufacturing. Buildings were later used for photographic and microfilm processing and for precision vertical drilling, boring, and milling operations. In the once sampling location within FA-6, only TCE was identified at concentrations that exceeded a PSV. TCE was, in fact, the only compound detected.

The extent of TCE within FA-6 in groundwater is presented on Figure 5-64. TCE concentrations are bounded by wells or piezometer samples where TCE was not detected. The relatively restricted areal extent of elevated TCE shown on Figure 5-64 is based on the very slight PSV exceedance that characterizes this plume. The vertical extent of TCE in groundwater is defined by deep bedrock monitoring wells located south (downgradient) of FA-6.

## **6.0 Contaminant Fate and Transport**

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This chapter addresses key components of the fate and transport of contaminants in groundwater at the RSA-147/148/149 site. Physical and chemical characteristics influence the tendencies of the site-related contaminants to degrade and/or migrate. The effects of physical, chemical, and biological processes on the contaminants control their potential fate (degradation) and transport (movement).

The fate and transport evaluation provides input to the human health risk assessment by identifying transport mechanisms working at the site and subsequently determining which exposure pathways are relevant to the risk evaluation. The information presented in this chapter also supports remedial alternative development in the corrective measures study phase. This RFI addresses groundwater contamination within the RSA-147/148/149 groundwater units and is supported by the findings and conclusions of investigations of associated surface media sites. Surface media RFIs are focused on evaluating the nature and extent of contamination in surface and subsurface soil, the surface water bodies directly impacted by surface media site runoff, and the groundwater contaminants associated with the surface media sites, both shallow and deep. Each surface media RFI contains a comprehensive evaluation of the future possibility that site-related contaminants may leach from soil and contribute to groundwater contamination beneath the site.

The evaluation in this chapter considers the contaminants in groundwater and the physical, chemical, and biological processes that impact the fate of the contaminants as they are transported from source areas to their eventual point of discharge or destruction. Critical to understanding fate and transport of chemicals within RSA-147/148/149 are hydrogeological considerations discussed in Chapter 3.0. These considerations include the following:

- Groundwater flow in the uppermost saturated zone is unconfined and, although complex, occurs in response to hydraulic gradient imposed by mapped potentiometric highs and lows.
- The groundwater within overburden and uppermost bedrock of the shallow groundwater flow zone is hydraulically interconnected.
- Groundwater flow in the deeper bedrock is (1) confined to semiconfined; (2) complex such that exact flowpaths are beyond resolution; and (3) occurs along localized fractures, faults, and solution conduits formed along the faults/fractures.
- Dye tracing studies have shown that (1) groundwater flowpaths have complex geometries that are generally directed from north (upland areas) to south (towards the

low-lying wetland areas flanking Huntsville Spring Branch and Indian Creek), (2) groundwater flow velocities generally are in the range of 500 to several thousand ft/day, and (3) dissolved constituent (i.e., dye) transport pathways of 3 to 5 miles in length exist.

- The depth of active circulation is limited due to reduced transmissivity with depth, except along faults that appear to act as preferred vertical pathways.
- Low-lying areas along Indian Creek and Huntsville Spring Branch form a broad area of terminal discharge of shallow and, to some degree, deep groundwater flow. Some portion of deeper groundwater flow may continue in a southerly direction beyond the discharge zone, particularly along confined flow zones.

**Primary and Secondary Sources of Contamination.** A source area is any part of the subsurface environment which contains mass of one or more site-related chemicals sufficient to degrade groundwater quality or prolong the recovery of groundwater to acceptable health-based standards. A review of source areas within RSA-147/148/149 is presented in Table 1-1.

Sources of contamination are either primary or secondary, as discussed in the following sections. Light nonaqueous-phase liquids have not been observed within RSA-147/148/149.

**Primary Source Areas.** A primary source of contamination is an area that received contamination via the transport of one or more chemicals directly from a release point. Primary sources of contamination include contaminated vadose-zone soil containing sufficient contaminant mass to function as ongoing and/or future threats to groundwater quality.

Numerous primary surface site sources of COCs exceeding PSVs have been identified within RSA-147/148/149. TCE is the most ubiquitous COC detected in these plume areas, followed by 1,1,2,2-TeCA, CBZ, beta-BHC, CT, alpha-BHC, aldrin, and 2-NT.

**Secondary Source Areas.** Secondary sources of contamination are created by primary sources and are discrete areas that contain contaminant levels high enough to continue to source plumes. For example, DNAPL can be considered a secondary source of contamination.

Subsurface DNAPL has been observed in shallow and deep groundwater within the boundaries of RSA-147/148/149. Indications of a secondary DNAPL source are presented in Table 5-1. The locations of indicated secondary sources of DNAPL in shallow groundwater are presented on Figure 5-1a and those for deeper groundwater are presented on Figure 5-1b. Although a number of the areas exhibiting DNAPL indications are within the MSFC boundaries, various Army DNAPL source areas also exist, as shown on Figures 5-1a and 5-1b.

**Contaminants of Interest.** As discussed in Chapter 4.0, RSA-147/148/149 groundwater and surface water samples have been analyzed for potential contaminants, including VOCs, SVOCs, PAHs, explosive compounds/perchlorate, TAL metals, and other parameters. Sources and resulting groundwater plumes are a function of the nature of the historical operations conducted within RSA-147/148/149, which include mustard and lewisite manufacturing (and related support functions), pesticide manufacturing, and waste disposal operations. Contaminants that were detected during recent sampling at concentrations above PSVs are listed in Table 4-2 for groundwater and 4-3 for surface water. Many of the contaminant detections were of low frequency or are degradation products of primary contaminants; therefore, the fate and transport evaluation focuses on contaminants that are among the most prevalent and best represent the chemical groups detected in RSA-147/148/149 groundwater. Contaminants of greatest concern include the following:

- VOCs: TCE, 1,1,2,2-TeCA, CBZ, CT, and PCE
- Pesticides: beta-BHC, alpha-BHC, aldrin, dieldrin, and DDT and metabolites
- SVOCs: dibenz(a,h)anthracene, naphthalene, bis(2-ethylhexyl)phthalate, and benzo(a)anthracene
- Explosive compounds: 2-NT
- PCBs: Aroclor 1242
- TAL metals.

**Commingled Plumes.** Contaminants often form commingled plumes within RSA-147/148/149 that may consist of two types which may occur singularly or in combination:

- Releases of multiple contaminants from proximal sources within the same former operational area result in commingled, co-contaminant plumes with a composite contaminant signature. As an example, wastes disposed at RSA-054/055 reflect multiple waste streams such that releases of CBZ and TCE from different points of disposal form a co-contaminant plume.
- Overlapping plumes from discrete source areas or historically different uses of contaminants at the same facilities. For example, associated with RSA-117 are discrete plumes of CBZ, TCE, various pesticides, and SVOCs from several former facility operations to form a discrete commingled plume.

Further commingling of plumes occurs along the complex network of subsurface conduits and pathways related to faulted, fractured, and karstic bedrock under the site. As illustrated from the dye tracing study conducted within RSA-147/148/149, dyes injected in apparently discrete

source areas emerged at common discharge points downgradient (Figure 3-12). Consequently, many of the source areas at RSA-147/148/149 appear to result in commingled plumes when considered at a larger scale. For example, the dye study indicated migration from the MSFC-034/RSA-049 area southward along deep fault planes that terminated at springs within the broad terminal groundwater discharge zone of the RSA-101 area.

Commingled plumes are also associated with releases within MSFC that are not the responsibility of the Army. The five major groundwater plumes associated with MSFC OU-3 groundwater (CH2M Hill, 2012b) contain similar contaminants to those released within RSA-147/148/149. Migration of shallow and deep groundwater from MSFC has been shown to discharge to surface water and springs south and west of the MSFC (CH2M Hill, 2012b). Dye tracing indicated some preferred pathways coincident with the MSFC are also oriented southeastward.

**Contaminant Transport Pathways.** Depending on the nature of the release, the chemicals of interest in RSA-147/148/149 groundwater can exist in the environment in any of four different phases: 1) as pure-phase compounds or in chemical mixtures above the solubility threshold; 2) as a dissolved phase in water; 3) sorbed to aquifer media; or 4) as a vapor in the vadose zone, capillary zone, or saturated zone overlying a plume. The nature of the release, in terms of form (nonaqueous-phase liquid or dissolved, liquid or solid), mass/volume, and rate of release, dictate the nature as well as the extent of the groundwater plume. DNAPL releases may migrate to considerable depth in response to a density greater than water, forming extensive, high-concentration plumes at multiple levels along the path of the DNAPL. Dissolved-phase plumes have the most impact on the shallow groundwater, following in response to hydraulic gradient and aquifer transmissivity.

**Groundwater.** Once in the groundwater, contaminant migration and persistence is controlled by the following factors:

- Volatilization (VOCs only) and potential accumulation as a secondary source
- Density-driven migration (for compounds denser than water)
- Advective flow
- Dispersion along flowpaths
- Diffusion
- Dilution
- Degradation (chemical and/or biologically mediated)
- Absorption/desorption processes.

As stated in Chapter 3.0, the hydrogeologic setting is fairly well defined; therefore, the contaminant migration processes in the karst aquifer beneath RSA-147/148/149 are well

understood and the exit pathways from the site are well defined. Dye tracing documented connections between points of injection and downgradient points of dye emergence, further documenting that the general flowpaths that terminate in springs in the broad wetlands along Indian Creek and Huntsville Spring Branch are well known. However, the specific flowpaths or movement of individual contaminants through the aquifer are likely complicated, nonlinear, and beyond resolution.

Locally, horizontal advective groundwater transport (i.e., transport of contaminants parallel to the groundwater flow direction) is occurring within overburden sediments beneath RSA-144/148/149. Dye trace results indicate groundwater flow, and therefore contaminant migration, within the aquifer is not exclusively controlled by the hydraulic gradient. Therefore, groundwater flow through the system is less dependent on the localized hydraulic gradient than it is on other hydrodynamic forces (river stage, upgradient recharge, etc.) that pulse groundwater through this three-dimensional system of horizontally and vertically interconnected voids and conduits. Karst features diminish vertically as the bedrock changes from a more soluble limestone to a less soluble chert-rich dolostone. Deeper groundwater flow (Lower Tuscumbia, upper and lower Fort Payne [Figures 3-3 and 3-4]) occurs through solution-enhanced bedding plane features (stylolites) and along fractures and faults. Within RSA-147/148/149, the majority of the groundwater within the karst aquifer is discharged to surface water bodies through springs and seepage.

**Surface Water and Sediment.** In addition to direct releases of contaminants to surface water, contaminants in surface water and sediment can also originate from the following processes:

- Discharge of contaminated groundwater into adjacent surface water bodies via springs
- Overland runoff of water and suspended particulate (particulates carrying contamination) which are transported directly into surface water.

Once in the surface water, contaminants can continue to be transported along with the surface water flow. The fate of contaminants in surface water is impacted by the same factors listed above for groundwater with the addition of the following processes:

- Photodegradation by sunlight
- Partitioning to (and from) sediment
- Uptake by plants.

The primary surface water bodies within RSA-147/148/149 are Huntsville Spring Branch in the southern portion of the sites and Indian Creek within RSA-149. A description of the occurrences of springs within the watershed is provided in Chapter 3.0. Wetlands occupy approximately

25 percent of the surface area of RSA-147/148/149 and are generally considered to represent an expression of the water table at the ground surface. Therefore, where contamination is present, it is anticipated that shallow groundwater has the potential to transport contamination to the wetlands. It should be noted again that the broad wetlands areas and springs in the vicinity of Huntsville Spring Branch and Indian Creek are terminal flow pathways for both shallow and deep groundwater.

**Vapor.** The vapor (air) migration pathway involves the partitioning of VOCs from soil and groundwater into air-filled soil pores. Subsequently, a percentage of the VOC-containing soil vapor volatilizes and escapes to surface air media. Chapter 7.0 evaluates the potential for VOC concentrations in soil vapor to pose a threat to human health.

**Fate of Environmental Contaminants in the Environment.** The fate of the site-specific contaminants in the groundwater beneath the RSA-147/148/149 site is discussed in the following sections. The physical and chemical fate of chemical contaminants in the environment is very dependent upon the physical and chemical characteristics of the contaminants of interest (Table 6-1).

**DNAPL.** DNAPL fate and transportation in the subsurface is influenced by the characteristics of the DNAPL release (volume, area, and time duration of the release), the properties of the DNAPL, the properties of the porous medium, and subsurface hydrologic conditions. Discussed below are factors that affect the residence time and migration of DNAPL in the subsurface environment. As discussed in Chapter 5.0, DNAPL within RSA-147/148/149 is primarily composed of TCE, CT, or CBZ. The occurrence of DNAPL at RSA-147/148/149 is presented on Figures 5-1a and 5-1b.

DNAPLs have relatively low viscosities that allow relatively rapid downward movement in the subsurface (Air Force Center for Environmental Excellence [AFCEE], 2000). Chlorinated solvent mobility in the subsurface increases with increasing density/viscosity ratios.

- The relatively low interfacial tension between a liquid chlorinated solvent phase and water allows a chlorinated solvent DNAPL to enter small fractures and pore spaces, facilitating deep penetration into the subsurface, providing there is sufficient mass to drive the migration.
- The high densities of the chlorinated solvents (1.2 to 1.7 grams per cubic centimeter) relative to that of water (1.0 gram per cubic centimeter) mean that if a sufficient volume of chlorinated solvent is spilled, then DNAPL may be able to penetrate the water table and continue to migrate under the influence of gravity. In the saturated zone, capillary forces can immobilize DNAPL at residual saturation in the soil. Alternatively, the unstable nature of DNAPL flow mechanisms can cause the solvent



to continue migrating as a continuous body or in thin "fingers," which can lead to the collection of large amounts of solvent in "pools" on top of less permeable layers.

- The low absolute solubilities of the chlorinated solvents (typically on the order of a few hundred milligrams per liter) mean that when a significant quantity of solvent is introduced to the environment, liquid solvent will dissolve slowly and persist for decades or centuries.
- The relatively low degree of partitioning to soil materials exhibited by the chlorinated solvents means that sorption to soils will not significantly retard the movement of a chlorinated solvent, and zones of contamination can expand quickly.

DNAPL transport is density driven and results in vertical migration of the mass of DNAPL in response to gravity. Some lateral spreading of the DNAPL is possible once an impermeable surface or lateral pathway, such as a bedding plane, is encountered. DNAPL has primarily been observed in shallow groundwater within RSA-147/148/149. Exceptions to this include RSA-053 and RSA-117, where DNAPL is indicated in deep groundwater. DNAPL occurrences are described in Chapter 5.0 and shown on Figures 5-1a and 5-1b. DNAPL release areas for which the Army is responsible include RSA-053, RSA-054, RSA-117, the northern portion of RSA-118, and MSFC-034.

### ***Dissolved-Phase Plumes***

**VOCs.** Chlorinated solvents commonly used in industrial applications, including TCE, PCE, 1,1,2,2-Tetra, cis-1,2-DCE, 1,1-DCA, 1,1-DCE, and VC, are relatively volatile, moderately soluble (a few hundred to a few thousand milligrams of solute per liter of water), and partition (adsorb) moderately to soil (Pankow and Cherry, 1996). In a pure chemical state, most chlorinated solvents are immiscible fluids. Chlorinated hydrocarbons are nonelectrolytes, in that they dissolve as neutral species and do not dissociate into cations or anions in aqueous solution. The chemical and physical behavior of chlorinated solvents is also affected by vapor pressure and molecular weight. Notably, if solubility and vapor pressure decrease and the ratio of chlorine atoms to molecular weight increases, then the tendency for a compound to adsorb to the soil increases.

**SVOCs.** Typically, SVOCs such as dibenz(a,h)anthracene, naphthalene, and benzo(a)anthracene have low solubility and a relatively high soil organic carbon to water partitioning coefficient ( $K_{oc}$ ). Therefore, the compound tends to remain bound to soil particles and is not a common constituent of contaminated groundwater.

**Pesticides.** Pesticides typically are not volatile, partition (adsorb) to soil (Pankow and Cherry, 1996), and have low solubility in water. As listed in Table 6-1, they have high  $K_{oc}$  values and

thus are retarded relative to other compounds, including VOCs. Pesticides are subject to degradation.

**Explosive Compounds.** Explosive compounds are generally characterized by a very low vapor pressure and moderate solubility in water. They typically have a low to moderate affinity to soil. Unlike the VOCs, they are not as soluble as the chlorinated compounds but once dissolved in water tend to stay in the aqueous phase. With  $K_{oc}$  values only slightly higher than the VOCs, they are mobile in the groundwater environment, whether in solution or sorbed to colloids.

**PCBs.** Although the degree of chlorination will affect the characteristics of PCBs, generally they have low vapor pressure and low water solubility, sorb rapidly to soil, and are fairly chemically inert.

**TAL Metals.** Typically, TAL metals are not volatile, sorb rapidly to soil, and are insoluble in water. A number of the metals have multiple valence states (including arsenic, chromium, manganese, and iron) and the presence and of these metals in solution is a function of the pH and/or redox conditions (oxidizing or reducing) of the water. The presence and mobility/fate in groundwater are controlled by these parameters. A number of the metals of interest are only present in solution under low pH and/or reducing conditions. Such conditions may exist locally at the point of historic release, but the nature of the aquifer creates oxic, neutral pH water that limit the overall mobility or extent of plume of these metals. The site-to-background evaluation (Appendix G) indicated anomalously high concentrations of arsenic, cadmium, chromium, iron, manganese, mercury, nickel, selenium, silver, and zinc in groundwater. A similar evaluation for surface water indicated arsenic, chromium, iron, nickel, and zinc are present at anomalously high concentrations. Typically, metals tend to be immobile in groundwater as they sorb rapidly to soil (McLean and Bledsoe, 1992).

**Attenuation Mechanisms.** All of the plumes within RSA-147/148/149 reflect past releases from operations that occurred 40 or more years ago. Consequently, it is expected that plumes would be stable to declining. Several locations within RSA-147/148/149 where three or more samples have been collected were considered to evaluate plume trends. Time-series plots were developed for each of these locations and are presented in Appendix H, along with a tabular summary of the concentration range and trend for each of the five most widespread contaminants in groundwater (Table H-1): TCE, CT, CBZ, 4,4'-DDD, and beta-BHC. Contaminant trends were developed for shallow and deep groundwater monitoring wells and springs within RSA-147/148/149 exclusive of MSFC. The individual plots, summary table and a map showing the locations plotted (Figure H-1) are provided in Appendix H.

In evaluating the concentration trends, the historical maximum detected result is compared to the most recent result for each location and parameter to determine whether the concentration is stable (no change), declining, or increasing over time. Table 6-2 provides a statistical summary of the location-specific trends presented in Table H-1. From this table, it is apparent that although between 5 and 11.5 percent of the locations showed increasing concentrations, the majority of the sampled locations are either stable or showing concentration declines over time. Concentrations declined from 0.1 to 100 percent depending on the contaminant and sampled location, but on average, plume concentrations are declining by 73 to 93 percent. For example, TCE was detected in 179 of the 198 locations evaluated. Of these, 2.2 percent showed no change while 88.3 percent of the locations showed concentration declines that ranged from 2.5 to 100 percent (no longer present). Only 9.5 percent of the locations showed an increase in TCE concentration over time.

In all cases, wells showing concentration increases were those where the most recent result was also the maximum result detected. In some cases, the increase was minimal and within the same order of magnitude of previous sample results from that location. In others, the increase was substantial and evidence of a long-term trend. There is no apparent pattern for the observed increases, which in most cases, coincide with decreases in other surrounding wells. Sites with wells with increases (such as RSA-010, RSA-053, RSA-054/055, RSA-060, RSA-062, and MSFC-034) are also those sites with the most long-term sampling records. All of these sites have nearby wells that are, in contrast, declining significantly. There is no apparent pattern for the observed increases, but fortunately those wells represent a small portion of the well network. Such locations are worthy of consideration for LTM in the corrective measures implementation phase.

The plume concentration declines are attributable to attenuation processes. Attenuation mechanisms describe those processes that result in a decrease in concentration or mass and include the following:

- **Physical Attenuation.** Physical attenuation refers to the dilution and dispersion of contaminant concentrations in surface waters or groundwater over time. Dilution and dispersion tend to enlarge contaminant plumes, causing a net decrease in contaminant levels at any one location. As the contaminant plume moves through the saturated medium, adsorption/desorption processes tend to slow chemical migration rates. Additionally, adsorption/desorption processes will tend to separate contaminant plumes as contaminants with high affinity to organic matter or clay minerals in soil particles will lag behind compounds with lower affinities to soil particles. Physical attenuation tends to depend upon the velocity of the particular water (e.g., a fast-moving stream versus a slow-moving river) and its rate of mixing.

- **Chemical or Biologically Enhanced Chemical Attenuation.** This component includes the collective assemblage of chemical or biologically enhanced reactions that result in the destruction of the parent compound. Daughter products created during the chemical transformation of the parent compound may be toxic or hazardous constituents (i.e., the degradation of TCE to cis-1,2-DCE). No chemical reactions (hydrolysis, photodegradation, etc.) working to reduce contaminant concentrations have been identified within the RSA-147/148/149 groundwater unit. However, biologically enhanced reductive dechlorination has been identified as a mechanism working to reduce TCE and other chlorinated ethene and ethane compounds within the aquifer. Perchlorate reduction by microorganisms is also likely occurring in site groundwater.

A complete evaluation of the biogeochemical processes at work within the aquifer is presented as Appendix I. A summary of this evaluation is presented in the body of this discussion on attenuation mechanisms. Although the DNAPLs beneath the site can be dissolved by soil pore water or groundwater and sequestered (rendered immobile, resulting in residual DNAPL) within the subsurface, there are no processes that attenuate DNAPL. DNAPL is generally toxic to microorganisms, and therefore the mass of DNAPL is resistant to biodegradation.

**Physical Attenuation Mechanisms.** Mechanisms and processes involved in physical attenuation of contaminants in groundwater include the following:

- **Adsorption** – Adsorption is a process in which dissolved constituents in water become attracted to soil particles and sediments. TCE and DNAPL have a low to moderate affinity to adsorb to soils; perchlorate has a relatively low affinity to soil or colloids in suspension in groundwater.
- **Dilution** – As the contaminated groundwater moves away from the source area, additional uncontaminated water is mixed in with the contaminated water, resulting in dilution of the contaminant.
- **Dispersion** – Contaminant movement in water is also controlled by the process of mechanical dispersion. Dispersive mixing causes some contaminant molecules to move ahead of (longitudinal to) and some molecules to move laterally (transverse) to the flowpath. The net effect is to spread (disperse) the contaminant plume along the advective front.
- **Volatilization** – The physical process by which constituents with high vapor pressures move from the liquid phase to the vapor phase without boiling is volatilization. Volatilization is not considered an important fate process for the TCE in the aquifer. However, once discharged into surface water bodies via a spring or through a seepage face, volatilization to the atmosphere can occur. Volatilization is not expected to be a significant fate process for the explosive compounds present in the water at the RSA-147/148/149 site.

Physical attenuation is a dominant process within RSA-147/148/149. Principal components include dilution and dispersion along flowpaths. Available data document sharp concentration declines surrounding interior plumes as well as multiple order-of-magnitude concentration declines between source areas and downgradient springs. This is supported by dye tracing with dyes injected in parts per million concentrations, with downgradient detections in wells and springs in the low parts-per-billion to parts-per-trillion concentrations. For example, Red 28 dye was injected at upgradient well Z-RS1237 at 20.9 parts per million and detected at a concentration of only 0.168 parts per billion in downgradient well F10-RS545, located along a fault 8,267 feet away. The dyes are conservative tracers, and this documents the significance of dilution and dispersion.

**Biological Attenuation Mechanisms.** The potential for biodegradation of RSA-147/148/149 contaminants in groundwater was evaluated to understand the impact that microbial processes are having on the site contaminant concentrations (Appendix H). A summary of biogeochemical conditions within the shallow and deep aquifer zones is included as Table I-3.

The present biodegradation conditions are summarized as follows:

- DO and Eh values in the shallow groundwater indicate mildly oxic, aerobic conditions, while reducing conditions are present in the deep groundwater.
- The presence of methane and sulfide in both the shallow and deep groundwater zones indicates that anaerobic microbes like methanogenic microorganisms and sulfate reducing bacteria are active in both zones.
- The presence of daughter products of chlorinated solvents TCE and trichloroethene in the groundwater indicates that some contaminant biotransformation is occurring. However, the lack of ethene and ethane indicates incomplete transformation. The geochemistry of the shallow groundwater indicates that conditions supportive of both reductive dechlorination and aerobic oxidation are present, although reductive dechlorination within the shallow groundwater is limited due to the mildly oxic, aerobic conditions that generally prevail. Conversely, conditions supporting reductive dechlorination in the deep groundwater are more commonly encountered.
- CT is being biodegraded under both nitrate- and sulfate-reducing conditions, as evidenced by the presence of chloroform, MC, and carbon disulfide.
- Elevated sulfate levels and low TOC levels throughout RSA-147/148/149 may be causing slow biotransformation of chlorinated solvents.
- Anaerobic CBZ biotransformation is occurring, based on the presence of benzene in areas of CBZ contamination. Aerobic biotransformation cannot be determined based on the data collected.

- Some biotransformation of explosive compounds might be occurring, as evidenced by the presence of amino-substituted daughter products. However, nitrate levels in some areas of the shallow groundwater may be at levels that are inhibitory to explosive degradation.
- Several pesticide byproducts are present in RSA-147/148/149, indicating the occurrence of biotransformation of DDT, heptachlor, and endrin.

**Contaminant Transport.** The following text presents processes by which contaminants may be transported within the groundwater.

**Particulate Transport.** Particulate transport refers to the movement of particles either as a suspended phase or as part of the bed load. Contaminants may be sorbed to colloids which are transported in suspension. The clay-rich nature of the overburden largely filters out particles such that particulate transport is less of a factor in the overburden. The karstic nature of the bedrock favors particulate transport, particularly in the upper Tuscomb Limestone where solution features are best developed. Significant particulate mass is commonly transported through conduits under turbulent flow conditions associated with recharge events. It is this transport mechanism that flushes the sediment and other load introduced from sapping of the overburden during sinkhole formation.

**Organic and Inorganic Solute Transport.** Most of the groundwater contaminants present in groundwater at RSA-147/148/149 are in the dissolved phase. The solutes, whether organic or inorganic, are advectively transported along with the flowing water. Advective flow velocities are based on the average (bulk) properties of the aquifer materials and the average hydraulic gradient causing flow, and they can be estimated by evaluating hydraulic conductivity. Hydraulic conductivity ranges for the primary subsurface units within RSA-147/148/149 are shown on Figure 3-10. Based on the range of hydraulic conductivity observed and assuming a constant hydraulic gradient, groundwater flow velocities vary and can range over many orders of magnitude within each unit. As described in Chapter 3.0, flow rates documented by dye tracing are high, ranging up to 2,200 ft/day. Along any given flowpath, solutes are subject to dispersion (lateral and longitudinal), diffusion (in or out of the aquifer matrix in response to concentration gradients), dilution, or otherwise being retarded due to adsorption/desorption to aquifer media.

**Density-Driven Transport.** As can be seen from Table 6-1, a number of the compounds present in groundwater have densities greater than water (i.e., greater than 1.0). Therefore, density-driven flow is possible, particularly when concentrations approach or exceed the solubility. This is clearly the case with DNAPL, where migration is density driven.

DNAPL movement through the vadose zone, the capillary fringe, and the saturated zone is controlled by a complex set of physical and chemical interactions. The physical and chemical relationships among the different fluids will often cause the DNAPL phase to migrate in complex ways, producing a contaminant source beneath a spill area that is very difficult or impossible to fully characterize (AFCEE, 2000).

The DNAPL itself contains two fractions: drainable and residual. If a drainable DNAPL fraction is large, it may occupy sufficient pore space to form a continuous fluid mass under positive nonaqueous-phase fluid pressure. A residual DNAPL fraction consists of smaller masses of DNAPL that become disconnected from the main fluid body and are held static by capillary tension.

The migration of a DNAPL is largely constrained by interfacial tension between the DNAPL and the wetting phase (water in pores). As a result of interfacial tension, nonwetting DNAPLs tend to form globules and irregular ganglia in water and water-saturated media. Nonaqueous-phase liquids denser than water (such as TCE) will migrate downward (under the influence of gravity) as a distinct liquid through the soil in the unsaturated zone. This vertical migration is typically accompanied by lateral spreading of the DNAPL due to the effects of capillary forces and heterogeneities in the porous medium (i.e., the path of least resistance). Even small differences in soil moisture content and grain size can provide sufficient capillary resistance to cause lateral DNAPL spreading in the vadose zone. However, downward movement will be enhanced and lateral spreading limited by dry conditions or transmissive vertical migration pathways for DNAPL migration (e.g., fractures, coarse-grained material, or boreholes).

Available analytical data suggest that DNAPL is or was present as a drainable phase and is present as a residual phase at several locations within RSA-147/148/149. With the exception of RSA-117, where DNAPL appears to have migrated to a depth approaching 300 feet bgs, most DNAPL occurrence appears restricted to overburden and shallow bedrock. DNAPL may be sequestered at any or all of the following points within the aquifer:

- As residual globules or ganglia in the overburden (both vadose and phreatic zones)
- Along or within cutters within the highly irregular epikarst (top of bedrock)
- Pooled within cavities and conduits in the highly karstic upper Tuscumbia underlying the epikarst zone
- Transported via sediment load downstream within conduits
- Within terminal fractures and joints in the upper Tuscumbia

- As residual ganglia along nonsealing faults or fault zones or pooled within sealed fault intervals
- Within or along open stylolites or fractures within the deeper bedrock (lower Tusculumbia and upper and lower Fort Payne)
- Perched above the naturally occurring hydrocarbons described in Chapter 2.0
- Possibly pooled in structural lows on the top of the Chattanooga Shale (or any other strata above it)
- Diffused into the rock matrix itself.

***Fate and Transport Evaluation of DNAPL and Dissolved-Phase Contaminants of Interest.*** Numerous compounds detected in RSA-147/148/149 groundwater exceeded PSVs, many of which (especially VOCs and pesticides) are soluble and therefore relatively mobile in the dissolved phase. In addition, localized secondary sources of groundwater contamination are present in the aquifer. SVOCs, TAL metals, and PCBs tend not to be mobile. The following text discusses the general fate and transport processes at work within the groundwater unit for the primary contaminants affecting groundwater.

***DNAPL.*** DNAPL transport is density driven and results primarily in vertical migration of the mass of DNAPL in response to gravity, although it is apparent that some lateral spreading of the DNAPL has occurred within the aquifer at RSA-147/148/149. From Figures 5-1a and 5-1b, the behavior or disposition of DNAPL in the subsurface can be generally described as follows:

- Following largely vertical migration paths from the point of release, the DNAPL may reside either in residual form within the unsaturated or saturated overburden (possibly accumulating at the overburden-bedrock interface in cutters), as residual or free product within the shallow bedrock, or in some cases extending to greater depths. DNAPL may be trapped in “dead-end” fractures, diffused into the rock matrix, or entrained within sediment in karst conduits. Vertical pathways are provided primarily by faults, as shown on Figures 3-3 and 3-4.
- The DNAPL mass continues to migrate vertically through the aquifer in response to gravity. The mass of DNAPL decreases with depth, as evident by comparison of Figures 5-1a (shallow) and 5-1b (deep). This mass attenuation of DNAPL is likely a result of the following factors:
  1. The mass of DNAPL decreases in size and volume as globules or ganglia of DNAPL are entrapped above the migration front, reducing the head and thus the ability to exceed the capillary pressure and interfacial tension.
  2. Additionally, vertical lithologic changes create an opportunity for DNAPL to spread laterally, thereby decreasing the mass of DNAPL available to move



vertically under gravitational forces. As shown on Figure 3-10, shallow subsurface material tends to express a greater hydraulic conductivity than deep material.

3. The DNAPL exposed to the flow of groundwater is continually, albeit slowly, dissolved in water and transported away in the dissolved phase, further reducing the DNAPL mass as a driving force for further vertical migration.

At depth, the shrinking DNAPL mass becomes immobilized because the migrating mass/volume of DNAPL cannot generate sufficient entry pressures to displace the water from the rock voids or fractures (or hydrocarbons) and continue to migrate. The distribution of DNAPL as reflected on Figures 5-1a and 5-1b represents static conditions for DNAPL at RSA-147/148/149.

**Groundwater.** The contaminants of primary interest can be segregated into three groups, based primarily on their physical and chemical properties:

- Chlorinated VOCs
- Pesticides
- Explosive compounds.

The primary contaminants impacting groundwater at RSA-147/148/149 (Table 4-2) are typically found commingled in discrete plumes. In general, VOCs, pesticides, and explosive compounds detected in the RSA-147/148/149 commingled groundwater plumes are moderately to very soluble and therefore relatively mobile in the dissolved phase. In contrast, SVOCs and metals are generally relatively immobile. The historical sources have typically been removed, and the total plume mass is limited.

**VOCs.** VOCs are generally mobile in groundwater, which may result in relatively extensive groundwater impact. TCE is the primary VOC contaminant contained within plume within RSA-147/148/149 and can be used as a surrogate to evaluate the fate and transport of VOCs in general. The surface sources of TCE releases have been removed or contained; therefore, no additional mass is likely to be added to the subsurface. The limited extent of plume areas indicates abiotic and biotic processes are acting on the plumes to mitigate migration. These processes have reached static conditions, and equilibrium has likely been attained. Equilibrium conditions are supported by trend plots presented in Appendix H. The trend plots for shallow groundwater zone wells MC-MW00-402, -403, -404 associated with MSFC-034 plumes all exhibit relatively constant concentrations over the past 15 years. The one deep well with more than three sample results at MSFC-034 (MC-MW00-403Db) does not span the same time frame as the other shallow wells but shows consistent concentrations over the time monitored.

At RSA-010, a number of shallow and deep wells have very long sampling records. A number of wells in this area have a record of over 15 years and show declining TCE concentrations in both shallow and deep groundwater zones. From review of trends in TCE, CT, and CBZ in wells with three or more sample results, the concentrations are stable (2 to 8 percent) or declining (80 to 88 percent of wells), with concentration declines averaging 73 to 81 percent of the historical maximum concentration. These data strongly suggest that the distributions of VOCs within RSA-147/148/149 are in static equilibrium or declining. In the majority of the wells, the concentrations of all VOCs are declining.

**Pesticides.** Pesticides by nature are generally immobile in groundwater and do not migrate appreciably from the source. The most pervasive pesticide impacting groundwater at RSA-147/148/149 is beta-BHC, and it is used as a surrogate to evaluate the fate and transport of pesticides. The surface sources of beta-BHC have been removed or contained; therefore, no additional mass is likely to be added to the subsurface. The limited extent of plume areas indicates abiotic and biotic processes are acting on the plumes to mitigate migration. These processes have reached static conditions, and equilibrium has likely been attained. Equilibrium conditions are supported by trend plots presented in Appendix H. The trend plots are presented for the shallow groundwater wells F60-RS025, -027, -028, -029, and -030, which are located in or adjacent to the former Olin pesticide manufacturing facility in RSA-117 (Figure H-1). Each of these trend plots exhibits declining concentrations over the sampled time frame. Deep wells in this plume area do not have a temporal data set sufficient to evaluate long-term trends; however, deep bedrock well F53-RS334 in RSA-053 does have pesticide data extending back to 1991. The trend plot for this well indicates a stable to slightly declining beta-BHC concentration over a period of over 20 years. Overall, comparing the most recent results to the historic maximum concentration shows pesticide concentrations are declining in 51 to 75 percent of the wells, with percent declines ranging up to 100 percent (nondetect in most recent samples). These data strongly suggest that the distributions of pesticide plumes within RSA-147/148/149 are in static equilibrium or declining.

**Explosive Compounds.** Explosive compounds by nature are moderately mobile in groundwater and can migrate appreciably from the source. Various explosive compounds were detected at concentrations above their PSVs within the RSA-147/148/149 shallow groundwater flow zone. The surface sources of explosive compounds have been removed or contained; therefore, no additional mass is likely to be added to the subsurface. Very few deep groundwater flow zone wells exhibited explosive compounds exceedances, and only five were detected at concentrations above the PSVs in surface water. The limited extent of explosive compounds plume areas indicates abiotic and biotic processes are acting on the plumes to mitigate migration.

These processes have reached static conditions, and equilibrium has likely been attained on a groundwater unit scale perspective.

**Groundwater Discharge to Surface Water.** Groundwater discharges to a number of springs within the broad discharge area along the downgradient portion of RSA-147/148/149. The discharge area coincides with wetlands that border Huntsville Spring Branch and Indian Creek. Consequently, groundwater discharges to surface water via these springs. Numerous surface water PSV exceedances (Table 4-3) were observed in these downgradient locations that appear disconnected from the interior plumes. VOCs and pesticides were the primary contaminants observed in surface water. Most PSV exceedances in surface water samples reflect discharge of impacted groundwater along fault-induced preferred pathways that discharge groundwater into low-lying wetland areas flanking Indian Creek and Huntsville Spring Branch. These surface water impacts reflect migration that is occurring very rapidly along these localized preferred pathways. In all instances, concentrations of contaminants in surface water, although exceeding surface water PSVs, are significantly less at the terminal discharge sample locations than at the upgradient core of the interior groundwater plumes.

**VOCs.** Presented in Table 6-3a are the primary surface water contaminant concentrations for collocated samples of groundwater (collected from the spring throat), surface water immediately above the spring, and downstream surface water samples, in addition to sediment contaminant concentrations at and downstream of the spring. It should be noted that the downstream samples are only a nominal distance (on the order of 10 to 20 feet) removed from the spring. It is evident from Table 6-3a that most sampled surface water is not impacted by VOCs. Where VOC concentrations exceeded the PSVs in groundwater at the springs, VOC-impacted groundwater and surface water was not found to impact sediment. The VOC concentrations emanating from springs do not appear to attenuate with distance downstream. As the VOCs impacting surface water tend to be volatile (Table 6-1), volatility and dilution will act on these VOCs with further downstream migration and likely reduce these elevated concentrations to below the PSVs. Some surface water samples above the spring and/or downstream of the spring show slightly higher concentrations than the groundwater collected from the spring. This may suggest discharge of groundwater into surface water that is already contaminated.

**Pesticides.** Presented in Table 6-3b are the primary surface water contaminant concentrations for collocated samples of groundwater (collected from the spring throat), surface water immediately above the spring, and downstream surface water samples, in addition to sediment contaminant concentration at and downstream of the spring. It is evident in Table 6-3b that pesticide concentrations do not appear to attenuate immediately downstream of the groundwater source. However, due to photodegradation and dilution, pesticide concentrations in surface water

discharged from springs will likely attenuate to below the PSVs with increasing distance from the groundwater source. At a number of locations, pesticides were detected in the sediment at the spring and/or downgradient but not in the surface water or spring (groundwater).

**Summary.** The following key points summarize the fate and transport of contamination in RSA-147/148/149 groundwater:

- The primary sources of groundwater impact within RSA-147/148/149 were from surface media sites within the groundwater units and within MSFC and are of limited mass.
- DNAPLs act as secondary sources of groundwater impact within RSA-147/148/149 that were observed within the groundwater units and within MSFC and are of limited mass.
- VOCs, pesticides, SVOCs, PCBs, explosive compounds, and TAL metals were detected in groundwater.
- Groundwater contamination within RSA-147/148/149 presents areas of limited extent and contaminants have reached static equilibrium and are either stable or declining due to biotic and abiotic attenuation processes.
- Groundwater-related surface water impact occurs primarily from springs emanating in the low-lying wetlands along Indian Creek and Huntsville Spring Branch as a result of terminal groundwater discharge in these areas from upgradient shallow and deep groundwater flowpaths. The principal COCs in groundwater discharge are VOCs, which should have low persistence once in the surface water environment due to volatilization and dilution. Available data show little attenuation of concentrations with (nominal) distance from the springs.

## **7.0 ARBCA Human Health Evaluation and Screening-Level Ecological Risk Assessment Summary**

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An ARBCA human health evaluation and a SLERA were performed for RSA-147/148/149. Details of the human health evaluation are presented in Appendix J and summarized in Section 7.1. The complete SLERA is provided in Appendix K and summarized in Section 7.2.

### **7.1 Human Health Alabama Risk-Based Corrective Action Evaluation**

The ARBCA evaluation was performed to assess human exposure to groundwater and surface water.

#### **7.1.1 Introduction**

The ARBCA evaluation consists of a three-tiered approach to site evaluation and development of risk-based target levels to guide corrective actions, if needed, as follows (ADEM, 2008):

- **Tier 1:** PSL evaluation, which involves comparing the MDCs of COPCs with PSVs. Chemicals with MDCs that exceed their PSVs are designated COCs and carried to the next tier.
- **Tier 2:** Risk Management (RM) 1 cumulative risk assessment based on ADEM (2008) default risk models and exposure assumptions. The RM-1 evaluation was not performed; instead, the evaluation proceeded directly to the Tier 3 evaluation as explained in Appendix J.
- **Tier 3:** RM-2 cumulative risk assessment, which is similar to the RM-1 evaluation, but permits the application of regulator-approved site-specific risk models and exposure assumptions.

The PSL evaluation consists of a simple comparison of site concentrations with their corresponding PSVs. Sites that pass the PSL evaluation may be released for unrestricted use with NFA, provided all other requirements are met. (In this context, “pass” means that chemical concentrations do not exceed their PSVs.) Evaluation of groundwater stopped with completion of the PSL tier. The surface water evaluation proceeded to the RM-2 tier.

Source media of interest at RSA-147/148/149 are limited to groundwater in two depth zones: shallow groundwater and deep groundwater. Shallow groundwater data consist of the analytical results of springs data and overburden, interface and shallow bedrock monitoring well data to a depth of 120 feet bgs. Deep groundwater data consist of the analytical results of deep bedrock monitoring wells, generally deeper than 120 feet bgs.

As discussed in detail in Section 1.6, six areas have been defined for which contaminant delineation responsibility resides with the RSA-147/148/149 groundwater units. These six areas are designated as FAs (FA-1 through FA-6) and are presented on Figure 4-4. Groundwater contamination identified within FA-1 through FA-6, as well as contamination identified at any singular sampling locations outside the FAs that are not the responsibility of a surface media site (Outside FA), are the focus of the risk evaluation. Detailed descriptions of FA-1 through FA-6 are provided in Chapter 5.0.

Exposure media of interest include groundwater hypothetically developed as a potable source and surface water evaluated in a recreational scenario. Separate shallow groundwater data sets were compiled for each FA of RSA-147/148/149, including the Outside FA. However, deep groundwater data were only evaluated at FA-2, FA-4, and Outside FA where deep bedrock monitoring wells were installed. The most recently detected concentration for each chemical from a given well was adopted as the representative concentration and used in the evaluation of that well. Shallow and deep groundwater are evaluated separately to provide perspective on the groundwater profile.

Surface and spring water sample locations are depicted on Figure J-8 in Appendix J. Surface water on RSA-147/148/149 has been divided into three different subareas or exposure domains based on location and the nature of exposures expected at each:

- **Indian Creek Subarea:** A perennial stream of sufficient size and depth to be evaluated in a swimming and fish consumption scenario.
- **Huntsville Spring Branch Subarea:** Sufficient size and depth to be evaluated in a swimming and fish consumption scenario.
- **RSA-122 Stream:** Smaller relatively shallow stream; evaluated in a wading scenario.

Soil gas, with VOCs sourced from groundwater, is another relevant exposure medium. Exposure to soil gas is likely to result from its intrusion into indoor space, where it is somewhat confined. Separate vapor intrusion evaluations were performed for each FA.

### **7.1.2 Groundwater Evaluation**

The MDCs of the COPCs in groundwater at each FA were compared with their PSVs to identify exceedances. PSVs for groundwater are preferentially ADEM MCLs, EPA MCLs, or the smaller of the EPA tap water RSLs based on an individual excess lifetime cancer risk (IELCR) of 1E-6 or a noncancer HI of 0.1. The most recently detected concentration for each chemical from a given well was used in the evaluation of that well.

The evaluation of groundwater stopped at the PSL tier. Any monitoring well with no chemicals identified as exceedances is described as “pass”; any monitoring wells with one or more exceedances is described as “fail.” Tabular summaries of the PSL evaluations for FA-1 through FA-6 are provided in Tables 7-1 through 7-6. Summaries of the PSL evaluations for Outside FA shallow groundwater and deep groundwater are provided in Tables 7-7 and 7-8, respectively. Wells that passed are indicated with a green dot and wells that failed are indicated with a red dot (Appendix J, Figures J-1 through J-7b). The results are summarized below by FA.

#### **7.1.2.1 FA-1 Groundwater Results**

As shown in Table 7-1, eight wells are located in FA-1 and were sampled from 2008 through 2013 variously for metals, explosive compounds, OPs, SVOCs, low-level PAHs, and VOCs. Only TCE exceeded its PSV in two wells (F56-RS049 and F57-RS731) at concentrations of 29 and 32 µg/L, respectively. All other wells passed the PSL evaluation. The PSL results are plotted on Figure J-1 of Appendix J.

#### **7.1.2.2 FA-2 Groundwater Results**

Groundwater evaluated at FA-2 included 62 shallow groundwater wells and 1 deep groundwater well. Monitoring wells were sampled from 2008 through 2017 variously for metals, explosive compounds, SVOCs, low-level PAHs, and VOCs.

**Shallow Groundwater.** COCs included the metals arsenic and manganese, five SVOCs, and four VOCs (Table 7-2). Twenty-three of the 62 shallow monitoring wells had one or more exceedances. PSV exceedances for arsenic and TCE account for the greatest number of shallow monitoring well failures, followed by bis(2-ethylhexyl)phthalate. The sample locations in which exceedances occurred are plotted on Figure J-2 of Appendix J.

**Deep Groundwater.** Only one deep bedrock monitoring well (F122-RS513) was included in the FA-2 PSL evaluation (Table 7-2). Groundwater for monitoring well F122-RS513 included data from samples collected in 2008, 2012, and 2013, and analyzed variously for the metals arsenic and mercury, SVOCs, low-level PAHs, and VOCs.

Arsenic and mercury were not detected. Three SVOCs and four VOCs were detected in deep groundwater; however, none of the concentrations exceeded their PSVs. Therefore, no COCs were identified in deep groundwater (Table 7-2). The bedrock well is plotted on Figure J-2 of Appendix J.

#### **7.1.2.3 FA-3 Groundwater Results**

The three shallow monitoring wells included in the FA-3 PSL evaluation are summarized in Table 7-3. Data from samples collected in 2008, 2012, and 2013 were analyzed variously for

perchlorate, OPs, PCBs, SVOCs, low-level PAHs, and VOCs. Metals were not included in the analytical suite for any sample.

COCs included the VOCs 1,1,2,2-TeCA, CT, and TCE (Table 7-3). All COC exceedances were detected in one well (147-RS1972) (Table 7-3). The other two wells had no exceedances. The PSL results are plotted on Figure J-3 of Appendix J.

#### **7.1.2.4 FA-4 Groundwater Results**

FA-4 groundwater includes data collected from shallow and deep groundwater monitoring wells. Separate PSL evaluations were performed for each depth zone.

**Shallow Groundwater.** Twenty-two shallow monitoring wells were included in the FA-4 PSL evaluation (Table 7-4). Monitoring wells were sampled from 2008 through 2017 variously for metals, perchlorate, explosive compounds, OPs, PCBs, SVOCs, low-level PAHs, and VOCs.

COCs included manganese, 10 explosive compounds, 6 OPs, and 9 VOCs (Table 7-4). PSV exceedances for VOCs (mainly CBZ, chloroform, and MC) account for the greatest number of shallow monitoring well failures. Fifteen of the 22 shallow monitoring wells had one or more exceedances. VOC and explosive exceedances were mainly from wells located in the NDA of RSA-053. The sample locations in which exceedances occurred are plotted on the FA-4 shallow groundwater map (Appendix J, Figure J-4).

**Deep Groundwater.** Only one deep bedrock monitoring well (F53-RS357) was included in the FA-4 PSL evaluation (Table 7-4). Groundwater for monitoring well F53-RS357 included data from samples collected in 2009 and 2012, and analyzed variously for metals, OPs, and VOCs.

OPs and VOCs were not detected. Thirteen metals were detected, but all concentrations were below BSVs. Therefore, no COPCs were identified and no PSL evaluation for deep groundwater was required.

#### **7.1.2.5 FA-5 Groundwater Results**

The shallow monitoring wells included in the FA-5 PSL evaluation are summarized in Table 7-5. Monitoring wells were sampled from 2008 through 2017 variously for metals, explosive compounds, OPs, SVOCs, low-level PAHs, and VOCs.

COCs included the metals arsenic and mercury, nitrobenzene, and five VOCs (Table 7-5). Eighteen of the 35 shallow monitoring wells had one or more exceedances, with TCE and CT accounting for the greatest number of shallow monitoring well failures (Table 7-5). Concentrations of TCE exceeding the MCL of 5 µg/L ranged from 270 to 6.2 µg/L.



Concentrations of CT exceeding the MCL of 5 µg/L ranged from 11,000 to 8.6 µg/L. Arsenic exceeded its MCL of 10 µg/L in two wells at concentrations of 340 and 60 µg/L. Mercury exceeded its MCL in one well. The PSL results are plotted on Figure J-5 of Appendix J.

#### **7.1.2.6 FA-6 Groundwater Results**

A single shallow monitoring well was sampled for the FA-6 PSL evaluation (Table 7-6). One sample was collected from this well in 2012 and analyzed for VOCs only. Only TCE was detected. As a result, the well was sampled again in 2017 but analyzed only for TCE. Therefore, the PSL evaluation included the TCE concentration from the 2017 sample and the remainder of the VOC concentrations from the 2012 sample.

TCE is the only chemical detected in shallow groundwater and the concentration exceeded its MCL (Table 7-6). The concentration of TCE from the 2012 sample was 7.3 µg/L; the concentration of TCE from the 2017 sample is slightly lower at 7.19 µg/L. The results of the FA-6 PSL evaluation are plotted on Figure J-6 of Appendix J.

#### **7.1.2.7 Outside Focus Area Results**

Groundwater contamination identified at any singular sampling locations outside the six FAs that are not the responsibility of a surface media site was also evaluated. Outside Area data include samples collected from shallow and deep groundwater monitoring wells. Separate PSL evaluations were performed for each depth zone.

**Shallow Groundwater.** One spring location (RSP-1501) and 77 shallow monitoring wells were included in the PSL evaluation for the Outside FA (Table 7-7). The spring sample and the monitoring wells were sampled from 2008 through 2017 and analyzed variously for metals, perchlorate, chemical agents and agent breakdown products, explosive compounds, OPs, PCBs, SVOCs, low-level PAHs, and VOCs.

All MDCs of chemicals were below their PSVs with the exception of benzo(a)anthracene, which slightly exceeded the PSV at well H62-RS045 (Table 7-7). The results of the Outside FA PSL evaluation are plotted on the shallow groundwater map (Appendix J, Figure J-7a).

**Deep Groundwater.** Five deep bedrock monitoring wells were included in the PSL evaluation for the Outside Area (Table 7-8). Deep groundwater included data from samples collected in 2008, 2009, and 2012, and analyzed variously for metals, perchlorate, and VOCs.

Perchlorate was not detected in any sample. All MDCs of chemicals were below their PSVs. Therefore, no COCs were identified in deep groundwater and all wells “passed” the PSL evaluation (Table 7-8) (Appendix J, Figure J-7b).

A summary of the PSL evaluations for each FA is provided in Table 7-9.

### **7.1.3 Surface Water Evaluation**

Surface water on RSA-147/148/149 has been divided into three different subareas or exposure domains based on location and the nature of exposures expected at each:

- Indian Creek Subarea: A perennial stream of sufficient size and depth to be evaluated in a swimming and fish consumption scenario.
- Huntsville Spring Branch Subarea: Sufficient size and depth to be evaluated in a swimming and fish consumption scenario.
- RSA-122 Stream: Smaller, relatively shallow; evaluated only in a wading scenario.

Chemicals detected in surface water across the three subareas/exposure domains are similar, reflecting the contamination of groundwater, and consist of a wide variety of metals, low levels of perchlorate, low concentrations of explosive compounds, a large number of OPs, and several VOCs. Two or three metals, perchlorate, and all the organic compounds (except 1,2-DCE [isomer not specified]) were identified as COPCs at each of the three subareas.

PSVs for identifying the COCs for surface water to carry to the cumulative risk assessment are selected in this order:

- Alabama WQC based on human health for consumption of drinking water and aquatic organisms (State of Alabama, 2014). The WQC for arsenic is based on a cancer risk level of  $1 \times 10^{-5}$ , as cited in the Administrative Code.
- National WQC based on the National Recommended Water Quality Criteria for human health consumption of water and organisms (EPA, 2014).
- Groundwater/tap water PSVs determined as described previously.

Chemicals identified as COCs are chromium for the Indian Creek Subarea, arsenic for the RSA-122 Stream, one or two explosive compounds, and several OPs and VOCs for each of the three subareas. Either the upper confidence limit or the MDC, as appropriate, was adopted as the representative concentration for the COCs in surface water with which to estimate cumulative risk.

A separate RM-2 cumulative risk assessment was performed for each of the three surface water subareas. The Indian Creek and Huntsville Spring Branch Subareas were assessed for swimming in a recreational scenario and for consumption of sport-caught fish as an indirect pathway for

exposure to surface water. The much smaller and shallower RSA-122 Stream was assessed only for wading in a recreational scenario.

The cumulative IELCR did not exceed the ADEM trigger level of  $1\text{E-}5$  and the cumulative HI did not exceed the threshold level of 1.0 for recreation exposure (swimming or wading) to any of the three subareas. Therefore, no chemicals in surface water were identified as relevant COCs for any of the three subareas for the recreational scenario (Table 7-10). However, the cumulative IELCR exceeded the ADEM trigger level and the cumulative HI exceeded the threshold level of 1.0 for the fish consumption scenario at the Indian Creek and Huntsville Spring Branch Subareas, due almost entirely to biomagnification of several OPs in fish (Table 7-10). Review of the risk calculation tables in Appendix J shows that the cancer risk and noncancer hazard from fish consumption exceeds the risk from swimming or wading by roughly two orders of magnitude. The OPs identified for inclusion in the fish consumption pathway generally possess the properties of persistence in the environment and high lipophilicity manifested by values of the logarithm of the octanol-water partition coefficient value greater than 3 that supports biomagnification.

#### **7.1.4 Vapor Intrusion Evaluation**

A vapor intrusion evaluation was performed based on the analysis of VOCs in soil gas and groundwater for which the groundwater units RSA-147/148/149 are responsible. Soil gas data were available from two soil vapor locations, 148-VP002 in FA-4 and 148-VP001 in FA-5. Groundwater VOC data are evaluated by FA. However, for FA-4 and FA-5, the soil gas data are judged to provide the more reliable basis for evaluating the potential for VOCs in groundwater to impact human health by the vapor intrusion pathway. VOCs detected in soil gas and groundwater were evaluated separately using the following two-step protocol:

- **Step 1:** Compare VOC concentrations in soil gas or groundwater with their respective target screening levels for residential exposure. VOCs in soil gas or groundwater with exceedances were carried to Step 2.
- **Step2:** Incorporate measured VOC concentrations in soil gas or groundwater, the agreed-upon facility-specific soil characteristics, and assumptions for a hypothetical future residential building into a mathematical model to estimate site-specific indoor air concentrations that were then compared with indoor air target screening levels. The hypothetical residential building evaluation is considered to be sufficiently protective also for occupants of commercial/industrial buildings.

Details of the vapor intrusion evaluation are presented in Appendix J, Tables J-54 through J-80. The vapor intrusion evaluations are summarized by FA in Sections 7.1.4.1 through 7.1.4.7 below and in Table 7-9.

#### **7.1.4.1 FA-1 Vapor Intrusion Evaluation**

The MDC of TCE in groundwater samples exceeded its target screening level. TCE was subjected to the Step 2 indoor air modeling exercise. The estimated indoor air concentration of TCE did not exceed its indoor air target screening levels at any of the risk levels. It is concluded that the VOCs detected in groundwater at FA-1 do not pose an unacceptable health threat by the vapor intrusion pathway (Table 7-9).

#### **7.1.4.2 FA-2 Vapor Intrusion Evaluation**

The MDCs of CT and TCE in groundwater samples exceed their target screening levels. CT and TCE were subjected to the Step 2 indoor air modeling exercise. The estimated indoor air concentration of CT did not exceed its indoor air target screening levels at any of the risk levels. The estimated indoor air concentration of TCE did not exceed its target screening level at a noncancer hazard of 1. It is concluded that the VOCs detected in groundwater at FA-2 do not pose an unacceptable health threat by the vapor intrusion pathway (Table 7-9).

#### **7.1.4.3 FA-3 Vapor Intrusion Evaluation**

The MDCs of 1,1,2,2-TeCA, CT, and TCE in groundwater samples exceed their target screening levels and were subjected to the Step 2 indoor air modeling exercise. None of the estimated indoor air concentrations of VOCs exceed their indoor air target screening levels at any of the risk levels. It is concluded that the VOCs detected in groundwater at FA-3 do not pose an unacceptable health threat by the vapor intrusion pathway (Table 7-9).

#### **7.1.4.4 FA-4 Vapor Intrusion Evaluation**

The FA-4 vapor intrusion evaluation was performed based on the analysis of VOCs in one soil gas sample and VOCs in groundwater samples collected at FA-4.

**Groundwater Evaluation.** The MDCs of 10 VOCs detected in groundwater samples exceed their target screening levels and were subjected to the Step 2 indoor air modeling exercise. The estimated indoor air concentrations of 1,1,2,2-TeCA, 1,1-DCA, 1,4-dichlorobenzene, benzene, CT, MC, and VC did not exceed their indoor air target screening levels at any of the risk levels. The estimated indoor air concentrations of chloroform and TCE did not exceed their target screening levels at a noncancer hazard of 1.0. However, CBZ exceeded its target screening level at all risk levels.

**Soil Gas Evaluation.** Soil gas data may eliminate the uncertainty associated with estimating VOC concentrations in soil gas from concentrations detected in groundwater. A number of VOCs detected in groundwater samples were not detected in soil gas samples, including CBZ. The MDCs of CT and chloroform exceed their target screening levels and were subjected to the

Step 2 indoor air modeling exercise. The other VOCs detected in soil gas samples, including TCE, did not exceed their target screening levels and are judged not to pose a threat to human health.

The estimated indoor air concentrations of CT did not exceed its indoor air target screening level at any of the risk levels. The estimated indoor air concentrations of chloroform did not exceed its target screening level at a cancer risk of 1E-05. It is concluded that the VOCs detected in soil gas do not pose an unacceptable health threat by the vapor intrusion pathway.

While the modeling of indoor air concentrations from groundwater data suggest that CBZ may represent a concern in indoor air, CBZ was not detected in soil gas, indicating that the groundwater modeling results may impart several orders of magnitude of conservatism. Based on the soil gas data for CBZ as well as other compounds detected in soil gas, is concluded that concentrations of VOCs in groundwater and soil gas do not pose an unacceptable health threat by the vapor intrusion pathway (Table 7-9).

#### **7.1.4.5 FA-5 Vapor Intrusion Evaluation**

The FA-5 vapor intrusion evaluation was performed based on the analysis of VOCs in one soil gas sample and VOCs in groundwater samples collected at FA-5.

**Groundwater Evaluation.** The MDCs of CT, TCE, and VC detected in groundwater samples exceed their target screening levels and were subjected to the Step 2 indoor air modeling exercise. The estimated indoor air concentrations of VC did not exceed its indoor air target screening level at any risk level. The estimated indoor air concentrations of TCE did not exceed its target screening level at a noncancer hazard of 1.0. However, CT exceeded its target screening level at all risk levels.

**Soil Gas Evaluation.** As mentioned previously, soil gas data may eliminate the uncertainty associated with estimating VOC concentrations in soil gas from concentrations detected in groundwater. A number of VOCs detected in groundwater samples were not detected in soil gas samples, including VC. None of the VOCs detected in soil gas samples, including CT and TCE, exceeded their target screening levels and are judged not to pose a threat to human health. It is concluded that the VOCs detected in soil gas do not pose an unacceptable health threat by the vapor intrusion pathway.

While the modeling of indoor air concentrations from groundwater data suggest that CT may represent a concern in indoor air, the soil gas concentration did not exceed its screening concentration, indicating that the groundwater modeling results may impart several orders of magnitude of conservatism. Based on the soil gas data for CT, TCE, and VC, as well as other

compounds detected in soil gas, it is concluded that concentrations of VOCs in groundwater and soil gas do not pose an unacceptable health threat by the vapor intrusion pathway (Table 7-9).

#### **7.1.4.6 FA-6 Vapor Intrusion Evaluation**

TCE is the only detected chemical at FA-6 and the MDC exceeds the target screening level. TCE was subjected to the Step 2 indoor air modeling exercise. The estimated indoor air concentration of TCE did not exceed its indoor air target screening levels at any of the risk levels. It is concluded that the VOCs detected in groundwater at FA-6 do not pose an unacceptable health threat by the vapor intrusion pathway (Table 7-9).

#### **7.1.4.7 Outside Focus Area Vapor Intrusion Evaluation**

The MDCs of CT and TCE in groundwater samples exceed their target screening levels. CT and TCE were subjected to the Step 2 indoor air modeling exercise. The estimated indoor air concentrations of CT and TCE did not exceed their indoor air target screening levels at any of the risk levels. It is concluded that the VOCs detected in groundwater at wells outside focus areas do not pose an unacceptable health threat by the vapor intrusion pathway (Table 7-9).

#### **7.1.4.8 Vapor Intrusion Evaluation Conclusion**

Based on the soil gas and groundwater data, it is concluded that concentrations of VOCs in groundwater and soil gas for the focus areas for which RSA-147/148/149 is responsible do not pose an unacceptable health threat by the vapor intrusion pathway.

### **7.1.5 Summary of Results and Conclusions for Groundwater Unit RSA-147/148/149 ARBCA Evaluation**

#### **Summary of Results for Groundwater**

The following chemicals detected in groundwater samples exceed their PSVs:

- FA-1 – TCE
- FA-2 – Arsenic, manganese, benzo(a)anthracene, benzo(a)pyrene, dibenz(a,h)anthracene, naphthalene, bis(2-ethylhexyl)phthalate, 1,1,2,2-TeCA, bromomethane, PCE, and TCE
- FA-3 – 1,1,2,2-TeCA, CT, and TCE
- FA-4 – Manganese, 10 explosive compounds, 6 OPs, and 9 VOCs
- FA-5 – Arsenic, mercury, nitrobenzene, 1,1-DCE, CT, chloroform, MC, and TCE
- FA-6 – TCE
- Outside FA – Benzo(a)anthracene.

## ***Summary of Results for Surface Water***

- Chemicals detected in surface water across the three subareas/exposure domains are similar, reflecting the contamination of groundwater, and consist of a wide variety of metals, low levels of perchlorate, low concentrations of explosive compounds, a large number of OPs, and several VOCs.
- COCs requiring further evaluation in an RM-2 cumulative risk assessment are chromium (Indian Creek Subarea); arsenic (RSA-122 Stream Subarea); and depending on the subarea, 1 or 2 explosive compounds, 7 to 10 OPs, and 4 or 5 VOCs.
- The cumulative IELCR did not exceed the ADEM trigger level of  $1E-5$  and the cumulative HI did not exceed the threshold level of 1.0 for recreational swimming or wading at any of the three surface water subareas.
- The cumulative IELCR exceeded the ADEM trigger level and the cumulative HI exceeded the threshold level of 1.0 for consumption of sport-caught fish from Indian Creek and Huntsville Spring Branch due to several OPs.

## ***Conclusions of ARBCA Evaluation***

- Potable use of groundwater from each focus area within RSA-147/148/149 would potentially pose an unacceptable risk to human health.
- Swimming or wading would not pose an unacceptable risk at any of the three surface water subareas.
- Consumption of sport-caught fish from Indian Creek and Huntsville Spring Branch would potentially pose an unacceptable risk to human health.
- VOC concentrations in shallow groundwater or soil gas are unlikely to pose an unacceptable risk to human health in a hypothetical future residential building.

## ***7.2 Screening-Level Ecological Risk Assessment Summary***

This section provides the summary of the SLERA for the RSA-147/148/149 groundwater units. The full SLERA is presented in Appendix K. It is important to note that this SLERA is based on screening-level comparisons, which are designed to be conservative. It may be that even where ecological hazards are determined to be possible that few, if any, impacts to ecological receptors within at RSA-147/148/149 are actually occurring or might occur in the future.

The SLERA for RSA-147/148/149 conforms to the guidelines set forth in the ARBCA guidance manual (ADEM, 2008) and was conducted in accordance with the RSA installation-wide work plan (IT, 2002) and final SLERA supplements to the installation-wide work plan (Shaw, 2010c). SLERAs at RSA include Steps 1, 2, and 3a of the EPA eight-step ecological risk assessment

process (EPA, 1997), as agreed upon by the Army, EPA Region 4, and ADEM (Redstone Arsenal Tier 1 Team, 2010).

The SLERA for RSA-147/148/149 was conducted in order to determine if this site is eligible for NFA in accordance with ADEM requirements. In the Permit, issued under the AHWMMMA, ADEM has specified that investigations must comply with AEIRG (ADEM, 2005) and ARBCA guidance. Therefore, to comply with ARBCA, including the provisions accepted by ADEM in RSA's installation-wide work plan, a SLERA was performed for this site.

### **7.2.1 Environmental Setting**

RSA-147/148/149 groundwater units have been consolidated into a single report based on their proximity, similarities, and cross-watershed transport. The consolidated RSA-147/148/149 groundwater unit covers approximately 8,800 acres in the south-central portion of RSA. The area that is now designated as RSA-147/148/149 was historically used for agricultural purposes and homesteads prior to the construction of Huntsville Arsenal in 1942.

RSA-147/148/149 underlies 82 surface media sites. Surface water and groundwater are dynamically interconnected at RSA-147/148/149 such that surface water plays an integral role in the overall hydrogeologic framework of the site. Because of the large size (approximately 8,800 acres) and other geographic features of RSA-147/148/149, the site has been subdivided into smaller subareas for evaluation in the SLERA. The following surface water subareas were evaluated in this SLERA with regard to the potential for groundwater impacts:

- Indian Creek Subarea
- Huntsville Spring Branch Subarea
- RSA-122 Stream.

The Indian Creek Subarea covers approximately 2,110 acres of riverine and wetland habitat that is predominantly composed of riverine and palustrine forested and emergent wetlands that are temporarily to permanently flooded. Within the Indian Creek Subarea, Indian Creek exhibits a braided, meandering channel with significant contribution from perennial springs. The vast majority of the Indian Creek Subarea lies within the 100-year floodplain, which reflects the propensity of the lower reaches of Indian Creek and the Tennessee River to flood upstream areas during high water periods.

The Huntsville Spring Branch Subarea encompasses 2475 acres of riverine open water habitats and palustrine forested, scrub/shrub, and emergent wetlands that are temporarily to semipermanently flooded in the southern portions of RSA-147, RSA-148, and RSA-149. Huntsville Spring Branch originates at Big Spring, which is located in downtown Huntsville,



north of RSA. Huntsville Spring Branch flows in a north-to-south direction near the eastern boundary of the RSA-145 groundwater unit before entering RSA. The initial flowpath of Huntsville Spring Branch is to the south, turning southwest near the southern boundary between the RSA-145 and RSA-147 groundwater units, where it is joined by McDonald Creek. Instead of following a direct southerly path towards the Tennessee River as other local streams do, Huntsville Spring Branch flows to the west and through the southern portions of RSA-147/148/149 before ultimately joining Indian Creek and discharging to the Tennessee River in the southwestern corner of RSA.

Stage fluctuations of the Tennessee River are propagated upstream along Huntsville Spring Branch such that actual backflow conditions exist within Huntsville Spring Branch in the reach within RSA-147/148/149. The backflow effect is most prevalent during high pool stage in the river. As the river stage declines during the transition to low pool, the backflow effect is not observed as far upstream. During the remainder of the time, normal downstream surface water flow conditions prevail in this reach. The majority of the Huntsville Spring Branch Subarea lies within the 100-year floodplain.

The significance of the backflow condition is that during high pool stage conditions in the summer, Huntsville Spring Branch upstream of Patton Road and in the southern portions of RSA-147/148/149 is the same elevation as the Tennessee River to the south. Under such conditions, Huntsville Spring Branch is a gaining reach. However, in winter months when the stream stage is higher than the low pool river stage, this reach of Huntsville Spring Branch is a losing reach. Under such conditions, the surface water is recharging groundwater.

The RSA-122 Stream is located along the eastern border of the RSA-147 groundwater unit and predominantly composed of upland wooded and developed areas, with the southern portion of the subarea exhibiting riverine and palustrine forested wetlands that are temporarily to semipermanently flooded. The RSA-122 Stream covers approximately 245 acres, approximately one-third of which lie within the 100-year floodplain. The perennial stream that flows north to south through this subarea receives surface runoff from the surrounding areas and also receives groundwater discharge from several perennial springs. This perennial stream flows southward to its confluence with Huntsville Spring Branch within the Huntsville Spring Branch Subarea.

The Williams Spring ecologically sensitive area (ESA) is located within the central portion of the Indian Creek Subarea and is designated as an ESA due to the presence of the Tuscumbia darter (*Etheostoma tuscumbia*), a federal species of concern. The Tuscumbia darter is a small, olive-brown fish (35 to 64 millimeters in length) with gold specks on its back, head, and upper side. This species is endemic to the Tennessee River drainage and is represented by several widely

scattered populations restricted to vegetated limestone springs. At RSA, small populations of Tuscumbia darters occur in the Williams Spring ESA and the JAYA Springs Complex ESA (Redstone Garrison, 2010).

### **7.2.2 SLERA Methodology**

The SLERA for RSA-147/148/149 assessed the potential impact groundwater may have on aquatic and semiaquatic habitats within RSA-147/148/149. The SLERA for RSA-147/148/149 entailed a screening-level approach consisting of the identification of preliminary chemicals of potential ecological concern (COPEC) through the calculation of screening-level hazard quotients ( $HQ_{\text{screen}}$ ) and a weight-of-evidence (WOE) evaluation of the preliminary COPECs.  $HQ_{\text{screen}}$  values were estimated using maximum detected constituent concentrations and RSA-specific ESVs. Potential impacts of groundwater discharge to surface water were evaluated by the calculation of  $HQ_{\text{screen}}$  values using each constituent's MDC in surface water and its corresponding surface water ESV. Potential impacts of groundwater constituents partitioning to sediment were evaluated by estimating constituent concentrations in sediment via equilibrium partitioning from spring throat groundwater. The modeled sediment concentrations were then used to estimate  $HQ_{\text{screen}}$  values using sediment ESVs. Constituents with  $HQ_{\text{screen}}$  values of 1.0 or greater, or those constituents for which no ESVs were available, were identified as preliminary COPECs and evaluated further in the WOE evaluation. Constituents with  $HQ_{\text{screen}}$  values less than 1.0 were considered to pose negligible ecological hazards and were not evaluated further in the SLERA.

The WOE evaluation considered the following lines of evidence in determining whether adverse impacts to surface water and sediment-dwelling (benthic) biota are potentially occurring from constituents in groundwater discharging to aquatic environs at the site.

- Alternate ESV sources such as the Los Alamos National Laboratory (LANL) Eco-Risk Database (LANL, 2012) for chemicals with no ESVs
- COPEC occurrence in site shallow groundwater (surface water COPECs only)
- Background concentrations (site concentrations compared to sitewide background concentrations)
- Upgradient concentrations (site concentrations compared to upgradient concentrations)
- Essential nutrients
- Frequency of detection

- Comparison of modeled sediment concentrations to empirical sediment data, if available (sediment COPECs only).

Sections 7.2.3 through 7.2.5 present the summaries of the SLERA results and conclusions for each of the RSA-147/148/149 subareas. The SLERA summaries and conclusions are also presented in Table 7-11.

### 7.2.3 Indian Creek Subarea SLERA Summary and Conclusions

Constituents that were identified as preliminary COPECs in surface water at the Indian Creek Subarea because they have  $HQ_{screen}$  values greater than 1.0 consisted of eight inorganics, eight pesticides, and one VOC. Perchlorate and Freon-113 were also identified as preliminary COPECs in surface water because there are no ESVs for perchlorate or Freon-113 in surface water (Table 7-11). Preliminary COPECs in surface water at the Indian Creek Subarea and their calculated  $HQ_{screen}$  values are summarized below:

<b>Chemical</b>	<b><math>HQ_{screen}</math></b>	<b>Chemical</b>	<b><math>HQ_{screen}</math></b>
Aluminum	45	4,4'-DDT	22
Cadmium	4.1	alpha-Chlordane	3.3
Chromium	10	Dieldrin	12
Iron	4.9	Endrin	4.3
Lead	4.2	Endrin Ketone	2.8
Manganese	3.7	gamma-Chlordane	4.7
Nickel	1.4	Heptachlor Epoxide	2.6
Thallium	1.4	Freon-113	NC
Perchlorate	NC	TCE	2.3
4,4'-DDD	2.0		

NC – Not calculated due to the absence of screening values.

Constituents that were identified as preliminary COPECs in spring throat groundwater at the Indian Creek Subarea because they have  $HQ_{screen}$  values greater than 1.0 consisted of one inorganic constituent, five pesticides, and one VOC. Aluminum, barium, calcium, iron, magnesium, manganese, potassium, sodium, vanadium, perchlorate, 2-ADNT, chloromethane, and Freon-113 were also identified as preliminary COPECs in spring throat groundwater because there are no ESVs or partitioning coefficients to calculate  $HQ_{screen}$  values (Table 7-11).

Preliminary COPECs in spring throat groundwater at the Indian Creek Subarea and their calculated  $HQ_{screen}$  values are summarized below:

<b>Chemical</b>	<b><math>HQ_{screen}</math></b>	<b>Chemical</b>	<b><math>HQ_{screen}</math></b>
Aluminum	NC	Perchlorate	NC
Barium	NC	2-ADNT	NC
Calcium	NC	4,4'-DDE	542
Chromium	348	4,4'-DDT	1084
Iron	NC	alpha-Chlordane	24

Chemical	HQ <sub>screen</sub>	Chemical	HQ <sub>screen</sub>
Magnesium	NC	Dieldrin	5
Manganese	NC	gamma-Chlordane	16
Potassium	NC	Chloromethane	NC
Sodium	NC	Freon-113	NC
Vanadium	NC	TCE	5.6

NC – Not calculated due to the absence of ESVs and/or partitioning coefficients.

WOE evaluations performed on the preliminary COPECs in surface water and spring throat groundwater at the Indian Creek Subarea determined the following:

### ***Surface Water***

- Aluminum, cadmium, iron, lead, manganese, and thallium were determined to be present in surface water at levels considered to be naturally occurring. Therefore, no further evaluation is warranted for these inorganics.
- Chromium and nickel were detected in one surface water sample at concentrations that have the potential to pose hazards to aquatic biota.
- Perchlorate was evaluated using alternate ESVs. Low hazard quotients (HQ) resulting from the alternate ESVs indicate adverse impacts to aquatic biota are not likely to occur.
- Eight pesticides were detected in surface water samples at concentrations that have the potential to pose hazards to aquatic biota. However, their low detection frequencies and low concentrations in surface water are likely the result of past agricultural land use and not the result of RSA-147/148/149 groundwater discharging to Indian Creek Subarea surface water.
- Freon-113 was detected in surface water samples at the Indian Creek Subarea, but there are no ESVs for Freon-113 in surface water; therefore, the potential for hazards to aquatic biota is uncertain.
- TCE in surface water at the Indian Creek Subarea has the potential to pose hazards to aquatic biota.

### ***Spring Throat Groundwater***

- Inorganics were determined to be present in spring throat groundwater at levels considered to be naturally occurring. Therefore, no further evaluation is warranted for these inorganics.
- Equilibrium partitioning of perchlorate from spring throat groundwater to sediment could not be performed due to the lack of a partitioning coefficient. Although empirical sediment data show that perchlorate has been detected in sediment, these detected concentrations of perchlorate in sediment cannot be quantitatively assessed due to the lack of a sediment ESV for perchlorate. Therefore, the potential impacts of

perchlorate in spring throat groundwater at the Indian Creek Subarea on benthic biota, while unlikely, remain uncertain.

- 2-ADNT was detected in one spring throat groundwater sample; however, there are no sediment ESVs for 2-ADNT in sediment. 2-ADNT was not detected in any of the sediment samples collected from the Indian Creek Subarea. Therefore, it can be concluded that 2-ADNT is likely not partitioning from spring throat groundwater to sediment in the Indian Creek Subarea and that ecological hazards from 2-ADNT in spring throat groundwater are unlikely.
- Five pesticides identified as preliminary COPECs in spring throat groundwater were also detected in sediment samples from the Indian Creek Subarea, albeit at lower concentrations than predicted by equilibrium partitioning. Empirical sediment data indicate that partitioning of 4,4'-DDE, 4,4'-DDT, alpha-chlordane, dieldrin, and gamma-chlordane from spring throat groundwater to sediment may be taking place and that these pesticides have the potential to pose hazards to benthic biota at the Indian Creek Subarea.
- Chloromethane and Freon-113 were identified as preliminary COPECs in spring throat groundwater because there are no ESVs for these VOCs in sediment. Chloromethane and Freon-113 were not detected in any sediment samples from the Indian Creek Subarea, which indicates that chloromethane and Freon-113 are not partitioning from spring throat groundwater to sediment and that ecological hazards from these two VOCs in spring throat groundwater are unlikely.
- TCE was detected in spring throat groundwater and sediment samples from the Indian Creek Subarea. These results indicate that partitioning of TCE from spring throat groundwater to sediment may be taking place; therefore, there is the potential for hazards to benthic biota from exposure to TCE in spring throat groundwater.

### ***SLERA Conclusions for the Indian Creek Subarea***

- Inorganics in groundwater at the Indian Creek Subarea of RSA-147/148/149 are unlikely to pose hazards to aquatic or benthic biota, with the possible exception of chromium and nickel in surface water, which have the potential to pose hazards to aquatic biota.
- 2-ADNT in groundwater at the Indian Creek Subarea is unlikely to pose hazards to aquatic or benthic biota because the detected concentrations in surface water are less than screening values and it is unlikely to partition to sediment.
- Perchlorate in groundwater at the Indian Creek Subarea is unlikely to pose hazards to aquatic biota because the detected concentrations of perchlorate in surface water are less than screening values, but the potential for perchlorate to pose hazards to benthic biota via partitioning from groundwater to sediment is uncertain.

- Pesticides in groundwater at the Indian Creek Subarea have the potential to pose hazards to aquatic biota and may also pose hazards to benthic biota via groundwater-to-sediment partitioning.
- Volatile organics in groundwater at the Indian Creek Subarea have the potential to pose hazards to aquatic biota and may also partition from groundwater to sediment and pose hazards to benthic biota.

#### 7.2.4 Huntsville Spring Branch Subarea SLERA Summary and Conclusions

Constituents that were identified as preliminary COPECs in surface water because they have  $HQ_{screen}$  values greater than 1.0 consisted of 11 inorganics, 9 pesticides, and 1 VOC. Perchlorate, tetryl, and chloroethane were also identified as preliminary COPECs in surface water because there are no ESVs for perchlorate, tetryl, or chloroethane in surface water (Table 7-11).

Preliminary COPECs in surface water at the Huntsville Spring Branch Subarea and their calculated  $HQ_{screen}$  values are summarized below:

**Preliminary COPECs in Surface Water – Huntsville Spring Branch Subarea**

Chemical	$HQ_{screen}$	Chemical	$HQ_{screen}$
Aluminum	232	Tetryl	NC
Barium	1.0	4,4'-DDD	14
Cadmium	4.5	4,4'-DDT	320
Chromium	3.9	alpha-Chlordane	3.0
Copper	2.3	Dieldrin	5.3
Iron	32	Endrin	6.3
Lead	14	Endrin Aldehyde	10
Manganese	66	gamma-Chlordane	19
Silver	106	Heptachlor	1.8
Vanadium	4.7	Heptachlor Epoxide	9.2
Zinc	1.2	Chloroethane	NC
Perchlorate	NC	TCE	6.2

NC – Not calculated due to the absence of screening values.

Constituents that were identified as preliminary COPECs in spring throat groundwater at the Huntsville Spring Branch Subarea because they have  $HQ_{screen}$  values greater than 1.0 consisted of two inorganics, nine pesticides, one SVOC, and one VOC. Aluminum, barium, calcium, iron, magnesium, manganese, potassium, sodium, vanadium, perchlorate, 2-ADNT, nitroglycerin, carbazole, chloroethane, and Freon-113 were also identified as preliminary COPECs in spring throat groundwater because there are no ESVs for these constituents in sediment and/or no partitioning coefficients to derive sediment concentrations (Table 7-11). Preliminary COPECs in spring throat groundwater at the Huntsville Spring Branch Subarea and their calculated  $HQ_{screen}$  values are summarized below:

**Preliminary COPECs in Spring Throat Groundwater – Huntsville Spring Branch Subarea**

Chemical	$HQ_{screen}$	Chemical	$HQ_{screen}$
Aluminum	NC	4,4'-DDD	4121

Chemical	HQ <sub>screen</sub>	Chemical	HQ <sub>screen</sub>
Barium	NC	4,4'-DDE	11920
Calcium	NC	4,4'-DDT	31879
Chromium	554	alpha-Chlordane	41
Copper	5	Dieldrin	3
Iron	NC	Endrin	1.5
Magnesium	NC	gamma-Chlordane	69
Manganese	NC	Heptachlor	842
Potassium	NC	Heptachlor Epoxide	37
Sodium	NC	Carbazole	NC
Vanadium	NC	Chrysene	2.7
Perchlorate	NC	Chloroethane	NC
2-ADNT	NC	Freon-113	NC
Nitroglycerin	NC	TCE	17.8

NC – Not calculated due to the absence of screening values and/or partitioning coefficients.

WOE evaluations performed on the preliminary COPECs in surface water and spring throat groundwater at the Huntsville Spring Branch Subarea determined the following:

### **Surface Water**

- Inorganics were determined to be present in surface water at levels considered to be naturally occurring. Therefore, no further evaluation is warranted for these inorganics.
- Perchlorate was evaluated using alternate ESVs. Low HQs resulting from the alternate ESVs indicate adverse impacts to aquatic biota are not likely to occur.
- Tetryl was detected at a frequency of less than 5 percent; therefore, it is unlikely to pose ecological hazards to aquatic biota.
- A number of pesticides were detected in surface water at concentrations that have the potential to pose hazards to aquatic biota. However, pesticides were detected at low concentrations that are likely the result of past agricultural land use and not the result of RSA-147/148/149 groundwater discharging to Huntsville Spring Branch Subarea surface water. Additionally, the Olin Consent Decree area (RSA-101) overlays a significant portion of the Huntsville Spring Branch Subarea and is a likely source of residual pesticide contamination (namely DDT and its metabolites).
- Chloroethane was detected at a frequency of less than 5 percent; therefore, it is unlikely to pose ecological hazards to aquatic biota.
- TCE in surface water has the potential to pose hazards to aquatic biota at the Huntsville Spring Branch Subarea.

### **Spring Throat Groundwater**

- Inorganics were determined to be present in spring throat groundwater at the Huntsville Spring Branch Subarea at levels considered to be naturally occurring, with

the possible exception of iron. Iron in groundwater could not be quantitatively assessed due to the absence of groundwater-to-sediment partitioning coefficients.

- Perchlorate and nitroglycerin in groundwater at the Huntsville Spring Branch Subarea are unlikely to pose hazards to benthic biota because they are unlikely to partition from groundwater to sediment.
- 2-ADNT in groundwater is unlikely to pose hazards to benthic biota because it was detected infrequently.
- Six pesticides identified as preliminary COPECs in spring throat groundwater were also detected in sediment samples from the Huntsville Spring Branch Subarea, albeit at lower concentrations than predicted by equilibrium partitioning. Empirical sediment data indicate that partitioning of 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-chlordane, gamma-chlordane, and heptachlor epoxide from spring throat groundwater to sediment may be taking place and these pesticides have the potential to pose hazards to benthic biota at the Huntsville Spring Branch Subarea. These pesticides are likely the result of past agricultural land use in the vicinity of RSA-147/148/149. Additionally, the Olin Consent Decree area (RSA-101) overlays a significant portion of the Huntsville Spring Branch Subarea and is a likely source of residual pesticide contamination (namely DDT and its metabolites).
- Dieldrin, endrin, and heptachlor in spring throat groundwater are unlikely to pose hazards to benthic biota due to their low frequency of detection.
- Carbazole in spring throat groundwater is unlikely to pose hazards to benthic biota because it is unlikely to partition from groundwater to sediment.
- Chrysene in groundwater has the potential to pose hazards to benthic biota via groundwater-to-sediment partitioning.
- Chloroethane and Freon-113 in spring throat groundwater are unlikely to pose hazards to benthic biota due to their low frequency of detection and low potential for partitioning from groundwater to sediment, respectively.
- TCE in spring throat groundwater has the potential to pose hazards to benthic biota via groundwater-to-sediment partitioning.

### ***SLERA Conclusions for the Huntsville Spring Branch Subarea***

- Inorganic constituents in groundwater and surface water at the Huntsville Spring Branch Subarea of RSA-147/148/149 are found at naturally occurring concentrations and are unlikely to pose hazards to aquatic or benthic biota, with the possible exception of iron in one spring throat groundwater sample. Iron in groundwater could not be evaluated quantitatively due to the lack of a partitioning coefficient to estimate iron concentrations in sediment.



- Perchlorate, tetryl, 2-ADNT, and nitroglycerin are unlikely to pose hazards to aquatic or benthic biota due to low frequencies of detection and low potential for partitioning from groundwater to sediment.
- Pesticides in groundwater at the Huntsville Spring Branch Subarea have the potential to pose hazards to aquatic biota and may also pose hazards to benthic biota via groundwater-to-sediment partitioning. However, the entire Huntsville, Alabama, area, including the present day RSA facility, was historically rural and largely used for agriculture. Pesticides were commonly used for agricultural purposes in this area, and the pesticides detected in spring throat groundwater and sediment at the Huntsville Spring Branch Subarea may have originated from these historical uses. Also, the Olin Consent Decree area (RSA-101) overlays a significant portion of the Huntsville Spring Branch Subarea. As such, pesticides detected in surface water and spring throat groundwater (namely 4,4'-DDD and 4,4'-DDT) may have originated in the Olin Consent Decree area.
- Carbazole in groundwater is unlikely to partition to sediment; therefore, it is unlikely to pose hazards to benthic biota.
- Chrysene may partition from groundwater to sediment and pose hazards to benthic biota.
- Chloroethane and Freon-113 in groundwater are unlikely to pose hazards to aquatic or benthic biota due to their low frequency of detection and low potential for partitioning from groundwater to sediment, respectively.
- TCE in groundwater has the potential to pose hazards to aquatic and benthic biota at the Huntsville Spring Branch Subarea.

### 7.2.5 RSA-122 Stream SLERA Summary and Conclusions

Constituents that were identified as preliminary COPECs in surface water at the RSA-122 Stream Subarea because they have  $HQ_{screen}$  values greater than 1.0 consisted of four inorganics and three pesticides. Perchlorate, tetryl, and trichlorofluoromethane were also identified as preliminary COPECs in surface water because there are no ESVs for perchlorate, tetryl, or trichlorofluoromethane in surface water (Table 7-11). Preliminary COPECs in surface water at the RSA-122 Stream and their calculated  $HQ_{screen}$  values are summarized below:

**Preliminary COPECs in Surface Water – RSA-122 Stream**

Chemical	$HQ_{screen}$	Chemical	$HQ_{screen}$
Aluminum	2.1	Tetryl	NC
Cadmium	1.5	4,4'-DDD	1.2
Lead	1.1	alpha-Chlordane	3.3
Manganese	1.9	gamma-Chlordane	3.6
Perchlorate	NC	Trichlorofluoromethane	NC

NC – Not calculated due to the absence of screening values.

Constituents that were identified as preliminary COPECs in spring throat groundwater at the RSA-122 Stream because they have HQ<sub>screen</sub> values greater than 1.0 consisted of two inorganics and four pesticides. Aluminum, barium, calcium, iron, magnesium, manganese, sodium, vanadium, perchlorate, and trichlorofluoromethane were also identified as preliminary COPECs in spring throat groundwater because there are no ESVs for these constituents in sediment and/or no partitioning coefficients to derive sediment concentrations (Table 7-11). Preliminary COPECs in spring throat groundwater at the RSA-122 Stream and their calculated HQ<sub>screen</sub> values are summarized below:

**Preliminary COPECs in Spring Throat Groundwater – RSA-122 Stream**

Chemical	HQ <sub>screen</sub>	Chemical	HQ <sub>screen</sub>
Aluminum	NC	Sodium	NC
Barium	NC	Vanadium	NC
Calcium	NC	Perchlorate	NC
Chromium	159	4,4'-DDE	704
Iron	NC	alpha-Chlordane	55
Magnesium	NC	gamma-Chlordane	11
Manganese	NC	Heptachlor	522
Mercury	2	Trichlorofluoromethane	NC

NC – Not calculated due to the absence of screening values and/or partitioning coefficients.

WOE evaluations performed on the preliminary COPECs in surface water and spring throat groundwater at the RSA-122 Stream determined the following:

### **Surface Water**

- Aluminum, cadmium, lead, and manganese were determined to be present in surface water at levels considered to be naturally occurring. Therefore, no further evaluation is warranted for these inorganics.
- Perchlorate and tetryl were evaluated using alternate ESVs. Low HQs resulting from the alternate ESVs indicate adverse impacts to aquatic biota are not likely to occur.
- Three pesticides were detected in surface water at concentrations that have the potential to pose hazards to aquatic biota. However, pesticides detected at low frequencies and at low concentrations are likely the result of past agricultural land use and not the result of RSA-147/148/149 groundwater discharging to RSA-122 Stream surface water.
- Trichlorofluoromethane was detected in one surface water sample; however, trichlorofluoromethane in surface water cannot be quantitatively assessed due to the lack of a surface water ESV. Therefore, the potential impacts of trichlorofluoromethane in surface water at the RSA-122 Stream on aquatic biota, while unlikely, remain uncertain.

### ***Spring Throat Groundwater***

- All of the inorganic preliminary COPECs were determined to be present in spring throat groundwater at levels considered to be naturally occurring. Therefore, no further evaluation is warranted for these inorganic constituents.
- Perchlorate, heptachlor, and trichlorofluoromethane in groundwater at the RSA-122 Stream are unlikely to pose hazards to benthic biota because they are unlikely to partition from groundwater to sediment.
- Three pesticides identified as preliminary COPECs in spring throat groundwater were also detected in sediment samples from the RSA-122 Stream, albeit at lower concentrations than predicted by equilibrium partitioning. Empirical sediment data indicate that partitioning of 4,4'-DDE, alpha-chlordane, and gamma-chlordane from spring throat groundwater to sediment may be taking place and these pesticides have the potential to pose hazards to benthic biota at the RSA-122 Stream.

### ***SLERA Conclusions for the RSA-122 Stream***

- Inorganic constituents in groundwater and surface water at the RSA-122 Stream are found at naturally occurring concentrations and are unlikely to pose hazards to aquatic or benthic biota.
- Perchlorate and tetryl are unlikely to pose hazards to aquatic or benthic biota at the RSA-122 Stream because detected concentrations of perchlorate and tetryl in surface water are below screening values and perchlorate has a low potential for partitioning from groundwater to sediment.
- Pesticides in surface water and groundwater at the RSA-122 Stream Subarea have the potential to pose hazards to aquatic biota and may also pose hazards to benthic biota via groundwater-to-sediment partitioning.
- Potential impacts of trichlorofluoromethane in surface water at the RSA-122 Stream Subarea on aquatic biota, while unlikely, remain uncertain. Impacts to benthic biota are unlikely due to the low potential for trichlorofluoromethane to partition from groundwater to sediment.

## **8.0 Summary and Conclusions**

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The following conclusions are based on key points presented in previous chapters of this RFI and summarized below.

- Chemicals released during historical activities at surface media SWMUs, including those within MSFC, contaminated groundwater within the 8,792 acres that comprise the RSA-147/148/149 groundwater units.
- RSA-147/148/149 groundwater has been characterized using an extensive network of monitoring wells (including smart “wells” at key locations along fault-related flowpaths) and springs. Collectively, this network monitors flow zones to and below the depth of active groundwater circulation.
- This RFI report presents data from groundwater samples and other environmental media collected from within the RSA-147/148/149 groundwater unit boundaries. This includes data from the various surface media site investigations as well as data obtained specifically from investigation of the groundwater units.
- The Army is responsible for groundwater associated with MSFC-034. NASA has responsibility for OU-3 groundwater and is taking advanced action on its impacts to the Indian Creek watershed. However, interpretation of surface media site data is presented in the various surface media site RFI reports. The focus of this RFI report is on delineation of groundwater contamination determined to be the responsibility of RSA-147/148/149.
- The number and distribution of samples and associated analytical results are adequate to determine the nature and extent of site-related chemicals in RSA-147/148/149 groundwater.
- Characterization data are representative of current groundwater conditions and are of acceptable quality and usability for meeting the RFI objectives.
- All groundwater contaminants identified as the responsibility of the RSA-147/148/149 groundwater units are delineated both laterally and vertically by monitoring locations where concentrations are below PSVs.
- Potable use of groundwater from multiple areas within RSA-147/148/149 would potentially pose an unacceptable risk to human health. Groundwater is not used as a source of potable water supply.
- Swimming or wading would not pose an unacceptable risk.
- Consumption of sport-caught fish from Indian Creek and Huntsville Spring Branch would potentially pose an unacceptable risk to human health.

- VOC concentrations in shallow groundwater and soil gas are unlikely to pose an unacceptable risk to human health in a hypothetical future residential building.
- Groundwater contaminants discharged to surface water have the potential to pose hazards to aquatic biota and may also partition from groundwater to sediment and pose hazards to benthic biota.

### ***Site Description and Physical Setting***

- RSA-147 (1,316 acres), RSA-148 (3,561 acres), and RSA-149 (3,915 acres) are 3 of the 13 groundwater units at RSA that collectively comprise 8,792 acres in the central portion of the facility.
- RSA-147/148/149 is generally bounded to the west by Indian Creek and associated wetlands and to the south by Huntsville Spring Branch and associated wetlands. Approximately 40 percent of RSA-147/148/149 lies within the 100-year floodplain, and wetlands occupy 27 percent of the surface area.
- Stream flow and stage vary seasonally and in response to reservoir operations on the Tennessee River (Wheeler Reservoir). During high-pool stage conditions (spring, summer, and fall), surface water may flow upstream along Indian Creek to Martin Road and along Huntsville Spring Branch to Patton Road.
- Land use within RSA-147/148/149 includes the following:
  - Industrial areas used by the Army for research, manufacturing, administration, and waste disposal
  - Undeveloped areas, including pastures, forests, and wetlands
  - MSFC, an area of approximately 1,840 acres where NASA has conducted space flight research since 1960; this includes NASA's groundwater unit (OU-3)
  - Olin Consent Order site (RSA-101).
- As a consequence of historical activities, RSA-147/148/149 contains 82 surface media SWMUs, 28 of which have been designated NFA SWMUs. RSA's Permit (ADEM, 2017a) lists MFSC sites for which Army is responsible. NASA is responsible for all groundwater within the MSFC boundary, including groundwater under Army surface media sites, with the exception of MSFC-034. Responsibility for MSFC's OU-3 remains with NASA and includes NASA's advanced action on its impacts to the Indian Creek watershed.
- NASA has identified five major shallow groundwater plumes originating from source areas at MSFC. These plumes (Northwest, Northeast, Central, Southeast, and Southwest) are composed mainly of chlorinated VOCs; TCE and its degradation products are the most common and widespread contaminants. The NASA plumes

have migrated downgradient in shallow groundwater and merged into deep bedrock groundwater.

- A 1983 consent decree governs Olin Corporation's remedial action for DDT contamination released to the Huntsville Spring Branch-Indian Creek System (RSA-101) between 1947 and 1970. The consent decree was established to isolate DDT from people and the environment and to minimize its transport downstream. Remedial actions conducted by Olin included burial in place of contaminated sediments and rerouting Huntsville Spring Branch to bypass the most heavily contaminated area.
- Bedrock underlying RSA-147/148/149 includes the basal Tuscumbia Limestone, the Fort Payne Formation, and the Chattanooga Shale. The Tuscumbia Limestone is the uppermost bedrock unit throughout most of southern portion of the study area. The Fort Payne Formation is the uppermost unit in the northern portion of the area because bedrock dips toward the south and the Tuscumbia Limestone was removed from this area by weathering and erosion. Bedrock is progressively more thinly bedded and cherty with increasing depth.
- Karst features control groundwater flow in bedrock. The bedrock surface exhibits considerable relief due to in situ weathering and dissolution. Solution-enlarged fractures and voids are well developed in the shallow bedrock and diminish with depth as the lithology changes. Therefore, groundwater data are segregated into shallow and deep. Shallow groundwater lies within the overburden and bedrock, which are hydraulically interconnected to form an unconfined water table aquifer. Deep groundwater lies within bedrock at depths greater than 120 feet bgs, where flow is semiconfined to confined locally within a limited number of small fractures. Geochemical data indicate slower groundwater flow (longer residence time) and increasing reducing conditions with increasing depth.
- Groundwater circulation or flow occurs between recharge and discharge areas. Active groundwater circulation is limited to the upper portions of the aquifer, where features capable of transmitting water are most abundant and best developed. The limit of active circulation does not lie at a specific depth but varies with proximity to fault-related fractures. Active groundwater circulation extends deeper along faults than in areas between faults.
- Bedrock is highly faulted, with a series of north-south-trending faults cutting across all of the bedrock units. Fractures associated with the faults provide discrete pathways for groundwater flow and provide connections between shallow and deep flow zones. Shallow groundwater flows in response to the potentiometric surface, although groundwater within the bedrock is constrained to flow through available fractures and voids. Deep groundwater flows through a much more limited network of fractures. Dye trace studies have demonstrated that bedrock groundwater may flow across divides that control shallow groundwater as well as the groundwater unit boundaries based on those divides. Groundwater in bedrock follows fault-related pathways for many miles at rates up to several thousand feet per day.

- Shallow groundwater and some portions of deep groundwater discharge to surface water from dozens of springs in the wetland system along Indian Creek and Huntsville Spring Branch. The springs serve as the terminal discharge points for overburden and bedrock groundwater and lie within a broad discharge zone that flanks Huntsville Spring Branch on both sides. Available data indicate the majority of groundwater originating within RSA-147/148/149 discharges within the broad discharge zone. Some underflow is possible, particularly associated with confined flow at depth. Upward vertical gradients were observed in multizone wells located south of Huntsville Spring Branch, supporting the potential for discharge of deeper groundwater to the broad discharge zone.

### ***Environmental Investigations and Data Usability***

- Since 1978, the Army and NASA have completed numerous investigations of the RSA-147/148/149 groundwater units and the surface media sites within them. Sampling locations where data were collected as part of these investigations have been assigned to either a surface media site or to the RSA-147/148/149 groundwater units. The responsibility for delineation of contaminants identified at those locations is likewise assigned to a surface media site or to the groundwater units.
- The RFI report for the RSA-147/148/149 groundwater units focuses on those data assigned to the groundwater units.
- The number and distribution of samples and associated analytical results are adequate to determine the nature and extent of site-related chemicals in RSA-147/148/149 groundwater.
- Characterization data are representative of current groundwater conditions and are of acceptable quality and usability for meeting the RFI objectives.
- Seismic surveys determined fault locations that greatly influence the development of karst features that control groundwater flow. Where possible, monitoring wells were placed along fault-related fracture zones to provide the most conservative horizontal and vertical delineation of groundwater contamination.
- Thermal infrared surveys document springs that serve as discrete points of groundwater discharge.
- Dye traces document groundwater flow velocities and vectors from source areas to downgradient wells and springs, supporting the value of these locations for groundwater monitoring.
- Springs were monitored during dye traces and sampled multiple times. Analytical results from 584 samples collected from 59 springs are available for evaluation.
- A total of 1,216 screening level groundwater samples were collected from 1,070 locations. Analytical data from these samples guided the siting of monitoring

well installations and bound the extent of groundwater contamination in the overburden.

- Collectively, the Army and NASA have installed 1,290 monitoring wells within RSA-147/148/149. Geological and potentiometric information from these locations is the basis for the understanding of the hydrogeologic framework. A total of 8,053 groundwater samples have been collected, and the analytical results from those samples are evaluated in this RFI. Additional wells will continue to be installed during surface media site investigations.
- In data from six groundwater unit-responsible focus areas and several outlier sampling locations, 35 chemicals were detected at concentrations that exceed their screening criteria, including 3 metals determined to represent contamination.
- Potential threats posed to populations of ecological receptors by chemicals in groundwater are evaluated based on data from surface water samples collected from three subareas: Indian Creek (Subarea 1), Huntsville Spring Branch (Subarea 2), and the RSA-122 Stream (Subarea 3).

### ***Nature and Extent of Contamination***

- Most PSV exceedances identified in focus areas are limited to the shallow groundwater, but contaminants at FA-4 extend into the deep zone. Based on dissolved-phase concentrations, DNAPL releases in groundwater unit-responsible areas may have occurred at RSA-053 (FA-4) and RSA-183 (FA-5).
- Dye tracing has demonstrated connections from upgradient sources to downgradient springs and wells in the groundwater discharge zone along Indian Creek and Huntsville Spring Branch. Groundwater follows multiple complex pathways through the bedrock to emerge at the springs. Flowpaths up to 15,915 feet long have been documented within RSA-147/148/149.
- The RSA-147/148/149 groundwater units have been characterized using an extensive network of wells (including smart “wells” at key locations along fault-related flowpaths) and springs. Collectively, this network monitors flow zones to and below the depth of active groundwater circulation.
- Within each of the six focus areas and outlier locations, all groundwater contaminants are delineated both laterally and vertically by monitoring locations where concentrations are below PSVs.
- VOCs, SVOCs, explosive compounds, pesticides, and three metals were detected in groundwater for which delineation is the responsibility of the RSA-147/148/149 groundwater units. The following key points summarize the nature and extent of these contaminants:

**VOCs.** In sampling locations determined to be the responsibility of the RSA-147/148/149 groundwater units, a total of 11 VOCs were detected in groundwater at concentrations that



exceed their PSVs. Two VOCs were detected at concentrations indicative of DNAPL: CBZ and CT.

- Historical sources for DNAPL include the following:
  - RSA-053, CBZ (FA-4)
  - RSA-183, CT (FA-5).
- TCE concentrations in three FAs form mappable plumes of limited and defined extent:
  - FA-1 (RSA-057)
  - FA-4 (RSA-053)
  - FA-5 (RSA-183).
- Other VOCs forming plumes of limited and delineated extent include the following:
  - CT - FA-5 (RSA-183)
  - CBZ, chloroform, MC, 1,1,2,2-TeCA, benzene - FA-4 (RSA-053).
- All VOC contaminants that are the responsibility of the groundwater units are delineated in the shallow and deep flow zones in each focus area by monitoring locations where concentrations are below the PSV or are not detected.

**SVOCs.** Six SVOCs at concentrations exceeding a PSV were detected in the shallow flow zone within FA-2. None of the exceedances form plumes. Benzo(a)anthracene was also detected in an outlier location for which delineation is the responsibility of the groundwater units. All SVOC contaminants that are the responsibility of the groundwater units are delineated in the shallow and deep flow zones in each focus area by monitoring locations where concentrations are below the PSV or are not detected.

**Explosive Compounds.** Ten explosive compounds exceeding PSVs were detected in the shallow flow zone within FA-4; one explosive exceeded its PSV in the shallow zone in FA-5.

- 2-NT forms a plume that is the responsibility of RSA-010, which encroaches into FA-4 (RSA-053).
- Nitrobenzene forms a plume of limited and delineated extent within FA-5 (RSA-183).
- All explosive contaminants that are the responsibility of the groundwater units are delineated in the shallow and deep flow zones in each FA by monitoring locations where concentrations are below the PSV or are not detected.

**Pesticides.** A total of six pesticides exceeded PSVs in samples from the shallow groundwater flow zone. All exceedances were detected in FA-4. Based on the data and discussions presented here, the following conclusions can be made.

- Clusters of PSV exceedances for three pesticides form plumes of limited and delineated extent:
  - beta-BHC
  - Aldrin
  - Dieldrin.
- All pesticides that are the responsibility of the groundwater units are delineated in the shallow and deep flow zones in each FA by monitoring locations where concentrations are below the PSV or are not detected.

**Metals.** Metals detected in groundwater and surface water at concentrations exceeding their PSVs and BSVs could be naturally occurring constituents of groundwater, originating from dissolution of minerals from the soil and bedrock through which the media flows. Therefore, metals concentrations in these media are evaluated using statistical and geochemical methods to determine whether a particular metal concentration is naturally occurring or is potential site-related contamination. The following summarizes those metals concentrations that are the responsibility of the groundwater units that exceed both their PSV and BSV and were determined to be statistically and/or geochemically anomalous.

- A total of three metals in shallow groundwater exceeded PSV and BSV screening values and were evaluated in the site-to-background comparison as anomalous and therefore site-related contamination.
- Anomalous concentrations of arsenic and manganese were detected in FA-2.
- An anomalous concentration of manganese was detected in FA-4.
- Anomalous concentrations of arsenic and mercury were detected in FA-5.
- Arsenic in both FA-2 and FA-5 is associated with historical lewisite manufacturing and processing at those sites. Lewisite is an arsenic-based chemical agent.
- All locations of anomalous metals concentrations are delineated by locations where metals concentrations are considered to be natural constituents of groundwater.

**Human Health and Ecological Risk Evaluations.** The following key findings and conclusions are derived from the ARBCA human health PSL risk evaluation, which was performed to assess human exposure to groundwater and surface water.

- Potable use of groundwater from multiple areas within RSA-147/148/149 would potentially pose an unacceptable risk to human health.
  - VOCs, particularly CBZ and chlorinated solvent residues, are the predominant risk drivers, followed in order by OPs, particularly the BHC isomers; explosive

compounds, particularly 2,4,6-trinitrotoluene degradation products; and several SVOCs. Metals are less significant.

- Swimming or wading would not pose an unacceptable risk at any of the three subareas: Indian Creek, Huntsville Spring Branch, or the RSA-122 Stream.
- Consumption of sport-caught fish from Indian Creek and Huntsville Spring Branch would potentially pose an unacceptable risk to human health.
- VOC concentrations in shallow groundwater and soil gas are unlikely to pose an unacceptable risk to human health in a hypothetical future residential building.

**Screening-Level Ecological Risk Assessment.** A SLERA assessed the potential impact groundwater may have on aquatic and semiaquatic habitats (surface water and sediment) in three subareas: Indian Creek, Huntsville Spring Branch, and the RSA-122 Stream. The SLERA is based on screening-level comparisons, which are designed to be conservative. Even where ecological hazards are determined to be possible, it is also possible that ecological receptors are not impacted and will not be impacted in the future.

The following key findings and conclusions are derived from the SLERA for the Indian Creek Subarea:

- VOCs in groundwater have the potential to pose hazards to aquatic biota and may also partition from groundwater to sediment and pose hazards to benthic biota.
- Pesticides in groundwater have the potential to pose hazards to aquatic biota and may also pose hazards to benthic biota via groundwater-to-sediment partitioning.
- 2-ADNT in groundwater is unlikely to pose hazards to aquatic or benthic biota and unlikely to partition to sediment.
- Perchlorate in groundwater is unlikely to pose hazards to aquatic biota; the potential for perchlorate to pose hazards to benthic biota via partitioning from groundwater to sediment is uncertain.
- Inorganic compounds in groundwater discharge are unlikely to pose hazards to aquatic or benthic biota, with the possible exception of chromium and nickel in surface water, which have the potential to pose hazards to aquatic biota.

The following key findings and conclusions are derived from the SLERA for the Huntsville Spring Branch Subarea:

- TCE in groundwater has the potential to pose hazards to aquatic and benthic biota.
- Chloroethane and Freon-113 in groundwater are unlikely to pose hazards to aquatic or benthic biota.

- Carbazole in groundwater is unlikely to pose hazards to benthic biota.
- Chrysene may partition from groundwater to sediment and pose hazards to benthic biota.
- Pesticides in groundwater have the potential to pose hazards to aquatic biota and may also pose hazards to benthic biota. However, land occupied by RSA and the entire Huntsville area were historically used for agriculture. Pesticides were commonly applied, and the pesticides detected in spring throat groundwater and sediment may have originated from these historical uses. Also, the Olin Consent Decree area (RSA-101) overlays a significant portion of the Huntsville Spring Branch Subarea. Therefore, pesticides detected in surface water and spring throat groundwater (namely 4,4'-DDD and 4'4'-DDT) may have originated in the Olin Consent Decree area.
- Perchlorate, tetryl, 2-ADNT, and nitroglycerin are unlikely to pose hazards to aquatic or benthic biota.
- Inorganic constituents in groundwater and surface water are found at naturally occurring concentrations and are unlikely to pose hazards to aquatic or benthic biota, with the possible exception of iron in one spring throat groundwater sample.

The following key findings and conclusions are derived from the SLERA for the RSA-122 Stream Subarea:

- The potential impacts of trichlorofluoromethane in surface water on aquatic biota are uncertain but unlikely. Impacts to benthic biota are unlikely.
- Pesticides in surface water and groundwater have the potential to pose hazards to aquatic biota and may also pose hazards to benthic biota. However, pesticides are likely present as the result of past agricultural land use and not RSA-147/148/149 groundwater discharge.
- Perchlorate and tetryl are unlikely to pose hazards to aquatic or benthic biota.
- Inorganic constituents in groundwater and surface water are found at naturally occurring concentrations and are unlikely to pose hazards to aquatic or benthic biota.

**Recommendation.** This report documents that the nature and extent of groundwater contamination have been determined and the RFI is complete. The Army recommends that ADEM move RSA-147, RSA-148, and RSA-149 from Table VI.2 to Table VI.6 to facilitate the implementation of corrective measures for groundwater.

## 9.0 References

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**ATTACHMENT 1**  
**LIST OF ACRONYMS**

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter
µg/m <sup>3</sup>	micrograms per cubic meter
°C	degrees Celsius
°F	degrees Fahrenheit
%D	percent difference
%R	percent recovery
1,1,2-TCA	1,1,2-trichloroethane
1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-Dichloroethene
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4,5-TP	2,4,5-trichlorophenoxypropionic acid
2,4-D	2,4-dichlorophenoxyacetic acid
2-ADNT	2-amino-4,6-dinitrotoluene
4-ADNT	4-amino-2,6-dinitrotoluene
AAC	Alabama Administrative Code
AAFES	Army and Air Force Exchange Service
AAP	Army Ammunition Plant
AB	ambient blank
ABLM	adult blood lead model
ABP	agent breakdown products
ABS	dermal absorption factor
ACAD	AutoCadd
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	asbestos-containing material
ACSIM	Assistant Chief of Staff for Installation Management
ADAF	age-determined adjustment factor
ADEM	Alabama Department of Environmental Management
ADPH	Alabama Department of Public Health
AEC	U.S. Army Environmental Command
AEDA	ammunition, explosives, and other dangerous articles
AEDB	Army Environmental Database
AEIRG	Alabama Environmental Investigation and Remediation Guidance
AEL	airborne exposure limit
AET	apparent effects threshold
AF	soil-to-skin adherence factor
AGS	Alabama Geographic Society
AHA	ammunition holding area
AHWMMA	Alabama Hazardous Wastes Management and Minimization Act
AIPH	Army Institute of U.S. Public Health
AL	Alabama
ALDOT	Alabama Department of Transportation
ALNHP	Alabama Natural Heritage Program
amb.	amber
AMRDEC	Aviation and Missile Research, Development, and Engineering Center
amsl	above mean sea level (1988 North American Vertical Datum, NAVD 88)
ANOVA	Analysis of Variance
AOC	area of concern
AOI	area of investigation
AP	armor piercing
APEC	areas of potential ecological concern
APHC	U.S. Army Public Health Center
APT	armor-piercing tracer
APTIM	Aptim Federal Services, LLC
AR	Army Regulation
AR/COC	analysis request/chain of custody
ARAR	applicable or relevant and appropriate requirement
ARBCA	Alabama Risk-Based Corrective Action
AREE	area requiring environmental evaluation
ARFO	ammunition returned from overseas
Army	U.S. Army
AS	air sparging
ASCII	American Standard Code for Information Interchange
ASP	Ammunition Supply Point
ASR	archives search report
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
ASV	alternative screening value
ASWCC	Alabama Soil and Water Conservation Committee
AT	averaging time
ATF	Bureau of Alcohol, Tobacco, Firearms and Explosives
atm-m <sup>3</sup> /mol	atmospheres per cubic meter per mole
ATS	alternative treatment standard
ATSDR	Agency for Toxic Substances and Disease Registry

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
ATTN	attention
ATV	all-terrain vehicle
AUF	area use factor
AWARE	Associated Water and Air Resources Engineers, Inc.
AWBC	alternative water balance cover
AWQC	ambient water quality criteria
AWQS	ambient water quality standard
B	Analyte detected in laboratory or field blank at concentration greater than the reporting limit (and greater than zero)
BAF	bioaccumulation factor
BAF <sub>soil-to-invert</sub>	soil-to-invertebrate bioaccumulation factor
BaOH	barium hydroxide
BAP	benzo(a)pyrene
BCF	bioconcentration factor
BCT	BRAC Cleanup Team
BDQM	bromodichloromethane
BEHP	bis(2-ethylhexyl)phthalate
BEM	Buried Explosion Module
BERA	baseline ecological risk assessment
BFB	bromofluorobenzene
BFE	base flood elevation
BFM	bonded fiber matrix
BG	Bacillus globigii
bgs	below ground surface
Bhate	Bhate Environmental Associates, Inc.
BHC	hexachlorocyclohexane
BHHRA	baseline human health risk assessment
BIM	basic information map
BIP	blow(n)-in-place
bkg	background
bls	below land surface
BMP	best management practice
BOD	biological oxygen demand
Bp	soil-to-plant biotransfer factors
BR	bedrock
BR-D	deep bedrock
BRAC	Base Realignment and Closure
BSAF	biota-to-sediment accumulation factors
BSC	background screening criterion
BSCRN	bottom of screen
BSV	background screening value
BTAG	Biological Technical Assistance Group
BTEX	benzene, toluene, ethyl benzene, and xylenes
BTOC	below top of casing
BTV	background threshold value
BW	body weight
BZ	breathing zone
C	ceiling limit value
C&D	Construction & Demolition
Ca	carcinogen
CA	chemical agent; corrective action
CAA	Clean Air Act
CAB	chemical warfare agent breakdown products
CACM	Chemical Agent Contaminated Media
CaCO <sub>3</sub>	calcium carbonate
CAIS	chemical agent identification set
CalEPA	California Environmental Protection Agency
CAMU	corrective action management unit
CAP	corrective action plan; Contractor Acquired Property
CAR	corrective action request
CARA	Chemical, Biological, Radiological, Nuclear, and High-Yield Explosives (CBRNE) Analytical and Remediation Activity
CAS	Chemical Abstracts Service
CASNO	Chemical Abstract Service identification number
CASRN	Chemical Abstracts Service Registry Number
CB	chlorobenzene
CB&I	CB&I Federal Services LLC
CBFM	colloidal borescope flowmeter
CBMPP	construction best management practices plan
CBR	chemical, biological, and radiological
CBRN	chemical, biological, radiological, nuclear
CBRNE	Chemical, Biological, Radiological, Nuclear, and High-Yield Explosives
CBZ	chlorobenzene
CCAL	continuing calibration
CCB	continuing calibration blank
CCC	criterion continuous concentration
CCl <sub>4</sub>	carbon tetrachloride
CCV	continuing calibration verification
CD	compact disk; Consent Decree

## List of Abbreviations and Acronyms Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
CDE	Chemical Defense Equipment
CDI	chronic daily intake
CDTF	Chemical Defense Training Facility
CEHNC	U.S. Army Engineering and Support Center, Huntsville
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERFA	Community Environmental Response Facilitation Act
CESAS	Corps of Engineers South Atlantic Savannah
CF	conversion factor
CFC	chlorofluorocarbon
CFDP	Center for Domestic Preparedness
CFR	Code of Federal Regulations
cfs	cubic feet per second
$C_{fw}$	contaminant concentration in fish from surface water
CG	phosgene (carbonyl chloride); cleanup goal
CGI	combustible gas indicator
ch	inorganic clays of high plasticity
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
CIH	Certified Industrial Hygienist
cis-1,2-DCE	cis-1,2-Dichloroethene
CK	cyanogen chloride
Cl	chloride, chlorinated
CLIN	contract line item number
$ClO_4^-$	perchlorate
CLP	Contract Laboratory Program
CLPILM	EPA CLP's prefix designation for the inorganic metals analysis statement of work
CLP M	EPA CLP's prefix designation for the mercury analysis statement of work
CM	corrective measure
cm	centimeter
cm/hour	centimeters per hour
$cm^2$	cubic centimeter
$cm^2/second$	square centimeters per second
$cm^3/g$	cubic centimeters per gram
CMA	U.S. Army Chemical Materials Activity; corrective measure alternative
CMC	criterion maximum concentration
CMD	corrective measures design
CMI	corrective measures implementation
CMICR	corrective measures implementation completion report
CMIP	corrective measures implementation work plan
CMO	corrective measure objective
CMS	corrective measures study
CMT	Continuous Multichannel Tubing
CN	chloroacetophenone
CNB	chloroacetophenone, benzene, and carbon tetrachloride
CNS	chloroacetophenone, chloropicrin, and chloroform
CO	carbon monoxide
$CO_2$	carbon dioxide
Co-60	cobalt-60
CoA	Code of Alabama
COAC	chemical of analytical concern
COC	when discussing chemicals, COC means chemical of concern; when discussing field paperwork, COC means chain of custody
COE	Corps of Engineers
COI	constituent of interest
Con	skin or eye contact
COPAC	chemical of potential analytical concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
COR	Contracting Officer's Representative
CP	communication plan; Competent Person
CPOM	coarse particulate organic matter
CPSS	chemicals present in site samples
CPVC	chlorinated polyvinyl chloride
$C_{pw}$	chemical of potential ecological concern concentration in pore water
CQA	construction quality assurance
CQAP	construction quality assurance plan
CRA	Conestoga-Rovers and Associates
CRDL	contract-required detection limit
CRL	certified reporting limit
CRP	community relations plan; compliance-related program
CRQL	contract-required quantitation limit
CRSA	Central Redstone Arsenal
CRZ	contamination reduction zone
CS	ortho-chlorobenzylidene-malononitrile
CSA	confirmation sampling activities
$C_{sed}$	chemical of potential ecological concern concentration in sediment from groundwater
CSEM	conceptual site exposure model
CSM	conceptual site model

## List of Abbreviations and Acronyms

### Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
CSP	chemical site plan
CSP	corrugated steel pipe
CSS	chemical safety submission
CT	carbon tetrachloride
CTC	cost to completion
ctr.	container
CVAA	2-chlorovinylarsenous acid
C <sub>w</sub>	contaminant concentration in water
CWA	when discussing chemicals, CWA means chemical warfare agent; when discussing laws, CWA means Clean Water Act
CWM	If used in the text of a document this acronym means chemical warfare material; if used in an analytical table which summarizes container requirements, this acronym means clear, widemouth container
CWS	Chemical Warfare Service
CX	dichloroformoxime
D	duplicate; duplicate contamination; when used as a validation qualifier, D means dilution
D2PC	Personal Computer Program for Chemical Hazard Prediction
DAD	average dermally absorbed dose
DAVS	detector-aided visual survey
D&I	detection and identification
DA	Department of the Army
DA PAM	Department of the Army Pamphlet
DAAMS	Depot Area Air Monitoring System
DA <sub>event</sub>	dermal dose absorbed per event
DAF	dilution-attenuation factor
DAF4	dilution-attenuation factor 4
DANC	decontamination agent, non-corrosive
DAP	diammonium phosphate
DASAF	Department of the Army Safety Office
DAVS	detector-aided visual survey
DBA	dibenz(a,h)anthracene
DBCP	1,2-dibromo-3-chloropropane
DC	District of Columbia
DCA	dichloroethane
DCB	decachlorobiphenyl
DCE	dichloroethene
DCMA	Defense Contract Management Agency
DCQAP	data collection quality assurance plan
DD	Decision Document
DD	Department of Defense (form only)
DDD	dichlorodiphenyldichloroethane (this is an industry standard acronym for this chemical)
DDE	dichlorodiphenyldichloroethene (this is an industry standard acronym for this chemical)
DDESB	Department of Defense Explosives Safety Board
DDT	dichlorodiphenyltrichloroethane
DEH	Directorate of Engineering and Housing
DEHP	bis(2-ethylhexyl)phthalate
DEMIL	Demilitarization Areas
DEP	depositional soil
DERP	Defense Environmental Restoration Program
DES	Directorate of Environment and Safety
DF	dilution factor
DFTPP	decafluorotriphenylphosphine
DFOW	Definable Feature of Work
DGM	digital geophysical mapping
DHC	<i>Dehalococcoides</i> sp.
DI	deionized
DID	data item description
DIMP	di-isopropylmethylphosphonate
DL	detection limit
DM	adamsite
DMBA	dimethylbenz(a)anthracene
DMM	discarded military munitions
DMMP	dimethylmethylphosphonate
DNAPL	dense nonaqueous-phase liquid
DNB	dinitrobenzene
DNBZ	dinitrobenzene
DNOC	4,6-dinitro-2-methylphenol
DNT	dinitrotoluene
DO	dissolved oxygen
DoD	U.S. Department of Defense
DODI	Department of Defense Instruction
DOJ	U.S. Department of Justice
DOT	U.S. Department of Transportation
DP	direct-push
DPDO	Defense Property Disposal Office
DPT	direct-push technology
DQCR	Daily Quality Control Report
DQO	data quality objective
DRMO	Defense Reutilization and Marketing Office

## List of Abbreviations and Acronyms Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
DRO	diesel range organics
DS	deep (subsurface) soil
DS2	Decontamination Solution Number 2
DSERTS	Defense Site Environmental Restoration Tracking System
DSMOA	Defense and State Memorandum of Agreement
DSN	Defense Switched Network
DTSC	Department of Toxic Substances Control
DU	decision unit
DUA	data usability assessment
DVD	digital versatile disc or digital video disc
DWEL	drinking water equivalent level
e.g.	for example
E3	Electromagnetic Environmental Effects
EB	equipment blank
EBS	environmental baseline study
EC <sub>20</sub>	effects concentration for 20 percent of a test population
EC <sub>50</sub>	effects concentration for 50 percent of a test population
ECBC	Edgewood Chemical and Biological Center
Eco-RGRG	ecological risk-based remedial goal
Eco-SSL	ecological soil screening level
ECM	earth covered magazine
ED	exposure duration
EDD	electronic data deliverable
EDQL	ecological data quality level
EDTA	ethylenediaminetetracetic acid
EE/CA	engineering evaluation and cost analysis
EF	exposure frequency
EFR	enhanced fluid recovery
Eh	oxidation-reduction potential
ELAP	Environmental Laboratory Accreditation Program
Elev.	elevation
EM(1)	electromagnetic
EM(2)	Engineer Manual
EM31	Geonics Limited EM31 Terrain Conductivity Meter
EM61	Geonics Limited EM61 High-Resolution Metal Detector
EMI	electromagnetic induction
Empirical	Empirical Laboratories, LLC
EMS/EL	Environmental Management Services, Inc./Environmental Laboratories
EMT	emergency medical technician
EOC	Emergency Operation Center
EOD	explosive ordnance disposal
EODT	explosive ordnance disposal team; EOD Technology, Inc.
EP	exit pathway
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EPDS	Emergency Personnel Decontamination Station
EPIC	Environmental Photographic Interpretation Center
EPP	Environmental Protection Plan
EPRI	Electrical Power Research Institute
EPT	Ephemeroptera, Plecoptera, Trichoptera
EQ	EQ Environmental Quality Company
EQL	estimated quantitation limit
ER	equipment rinse; USACE Engineer Regulation
ERA	ecological risk assessment
ERH	electrical resistive heating
ERIS	Environmental Restoration Information System
ER-L	effects range-low
ER-M	effects range-medium
ESA	ecologically sensitive area
ESB	Equilibrium Partitioning Sediment Benchmark
ESE	Environmental Science and Engineering, Inc.
ESL	ecological screening level
ESP	explosives site plan
ESMP	Endangered Species Management Plan; Explosives Safety Management Program
ESS	explosives safety submission
ESTCP	Environmental Security Technology Certification Program
ESV	ecological screening value
ET	exposure time
ET <sub>sw</sub>	exposure time - surface water
EU	exposure unit
EUR	Environmental Use Restriction
EV	event frequency
E-W	east to west
Excel	Excel Geophysical Services
Exp.	Explosives
ExplorTech	ExplorTech, LLC
EXTOXNET	Extension Toxicology Network



# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
Ey	Etowah silty clay loam
EZ	exclusion zone
FA	focus area
FA	fraction absorbed
FAC	facultative wetland
FACU	facultative upland
FACW	facultative wetland
FADL	Field Activity Daily Log
FAR	Federal Acquisition Regulations
FAV	final acute value
FB	field blank
FBI	Family Biotic Index
FCSV	food chain screening value
FCV	final chronic value
FD	field duplicate
FDA	U.S. Food and Drug Administration
Fe <sup>+2</sup>	ferrous iron
Fe <sup>+3</sup>	ferric iron
FEC	fluid electrical conductivity
FedEx	Federal Express, Inc.
FEMA	Federal Emergency Management Agency
FFA	Federal Facilities Agreement
FFCA	Federal Facilities Compliance Act
FFE	field flame expedient
FFP	firm fixed price
FFS	focused feasibility study
FI	fraction of exposure; filtered
FID	flame ionization detector
FIFRA	Federal Insecticide, Fungicide, & Rodenticide Act
FLUTE	Flexible Liner Underground Technologies, Ltd. Co.
FM-ARNGTC	Fort McClellan Army National Guard Training Center
FMDC	Fort McClellan Development Commission
FML	flexible membrane liner
f <sub>oc</sub>	fraction organic carbon
FOIA	Freedom Of Information Act
FOMRA	Former Ordnance Motor Repair Area
FOST	Finding of Suitability to Transfer
Foster Wheeler	Foster Wheeler Environmental Corporation
FR	Federal Register
Frtn	fraction
FS	feasibility study
FSH	Fort Sam Houston
FSP	field sampling plan
FS smoke	sulfur trioxide and chlorosulfonic acid
ft	foot, feet
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year
ft <sup>2</sup>	square feet
ft <sup>2</sup> /day	square feet per day
FTA	Fire Training Area
FUP	fixed unit price
FWV	fieldwork variance
FY	fiscal year
g	gram
G&M	Geraghty and Miller, Inc.
g/cm <sup>3</sup>	grams per cubic centimeter
g/m <sup>2</sup>	grams per square meter
g/m <sup>3</sup>	gram per cubic meter
G-856	Geometrics, Inc. G-856 magnetometer
G-858G	Geometrics, Inc. G-858G magnetic gradiometer
GA	tabun
GAC	granular activated carbon
GAF	General Aniline and Film; gastrointestinal absorption factor
gal	gallon
gal/min	gallons per minute
GB	sarin (isopropyl methylphosphonofluoridate)
GC	gas chromatograph
GC/MS	gas chromatograph/mass spectrometer
GCL	geosynthetic clay liner
GCMR	Geophysical Classification for Munitions Response
GCWD	Gulf Chemical Warfare Depot
GCWS	Gulf Chemical Warfare Service
GEAE	Generic Ecological Assessment Endpoint
GEDIT	gaseous electron donor injection technology
GFAA	graphite furnace atomic absorption

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
GIP	geophysical investigation plan
GIS	geographic information system
GNSS	Global Navigation Satellite System
GPCR	gas phase chemical reduction
gpm	gallons per minute
GPR	ground-penetrating radar
GPS	global positioning system
GRA	general response action
GRIM	Groundwater Responsibility Information Matrix
GRO	gasoline range organics
GS	ground scar
GSA	when discussing the federal government requirements, GSA means General Services Administration; when discussing geology, GSA means Geologic Survey of Alabama
GSE	Great Southern Engineering
GSR	green and sustainable remediation
GST	ground stain
GSV	geophysical systems verification
GUC	groundwater use control
GW	groundwater
GWDT	Groundwater Design Team
GWMZ	groundwater monitoring well, multizone
GWTR	groundwater monitoring well
H&S	health and safety
H <sub>2</sub> O <sub>2</sub>	hydrogen peroxide
H <sub>2</sub> S	hydrogen sulfide
HA	hand auger; hazard assessment
HAL	Health Advisory level
HAMUST56	Huntsville Arsenal Mustard Plant 2, Lines 5 & 6
Harmon	Harmon Engineering Associates, Inc.
HAZMATCAD™	Hazardous Material Chemical Agent Detector
HAZWOPER	Hazardous Waste Operations and Emergency Response
HBESL	health-based environmental screening level
HC	mixture of hexachloroethane, aluminum powder, and zinc oxide (smoke producer)
HCl	hydrochloric acid
HD	distilled mustard (bis-[dichloroethyl]sulfide); hazard division
HDPE	high-density polyethylene
HE	high explosive
HEAST	Health Effects Assessment Summary Tables
HEAT	High Explosive Anti-Tank
Herb.	herbicides
HFD	hazardous fragment distance
HHAWQS	human health Alabama water quality standard
HHRA	human health risk assessment
HHRE	human health risk evaluation
HI	hazard index
HI <sub>COC</sub>	total hazard index for a given relevant COC, for a given receptor added across all exposure routes for given source medium
HI <sub>cum</sub>	cumulative hazard index summed across chemicals and source media
HI <sub>TO</sub>	total hazard index for a given target organ for a given receptor
Hm	hot measurement
HMW	high molecular weight
HMX	cyclotetramethylenetetranitramine; octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocane
HN	hydrogen mustard
HNC	hydrogen cyanide
HNO <sub>3</sub>	nitric acid
HP	hydropunch
HPLC	high-performance liquid chromatography
HQ	hazard quotient
HQ <sub>COCi</sub>	hazard quotient for the target organ of interest estimated for the ith COC
*HQ <sub>i</sub>	hazard index for a given chemical summed across exposure routes and source media
*HQ <sub>Ri</sub>	hazard quotient for the given chemical for exposure route i
HQ <sub>screen</sub>	screening-level hazard quotient
hr	hour
HRR	Historical Records Review
HS	mustard
HSA	hollow-stem auger
HSB	Huntsville Spring Branch
HSDB	Hazardous Substances Data Bank
HSMR	Huntsville Spring Branch at Martin Road
HT	British Mustard
HTPB	hydroxy-terminated polybutadiene
HTRW	hazardous, toxic, and radioactive waste
HTW	hazardous and toxic waste
HUB	Historically Underutilized Business
HWCL	hazardous waste control limit
HWSU	hazardous waste storage unit
HY	hydrostratigraphic unit

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
HYPN	hydropunch
Hz	hertz
I	out of control, data rejected due to low recovery
I-565	Interstate 565
IAP	Installation Action Plan
IATA	International Air Transport Authority
I-AVSS	instrument-aided visual surface sweep
ICAL	initial calibration
ICAM	improved chemical agent monitor
ICB	initial calibration blank
ICP	inductively coupled plasma
ICS	interference check sample
ICV	initial calibration verification
ID	identification; inside diameter
IDL	instrument detection limit
IDLH	immediately dangerous to life or health
IDM	investigative-derived media
IDQTF	Intergovernmental Data Quality Task Force
IDS	intrusion detection system
IDW	investigation-derived waste; investigative-derived waste
i.e.	that is (in other words)
IELCR	individual excess lifetime cancer risk
IELCR <sub>occ</sub>	total individual excess lifetime cancer risk for a given relevant chemical of concern, for a given receptor added across all exposure routes for a
'IELCR <sub>Cum</sub>	cumulative cancer risk for a given receptor summed across chemicals and source media
'IELCR <sub>Ri</sub>	cancer risk for the given chemical in a given source medium for exposure route i
'IELCR <sub>T</sub>	total cancer risk for the given chemical in a given source medium summed across exposure routes
IELCR <sub>(Ti)</sub>	total cancer risk for chemical i in a given source medium summed across exposure routes
IEOC	Installation Emergency Operations Center
IEUBK	Integrated Exposure Uptake Biokinetic
IF	ingestion factor; inhalation factor
IIP	intrusive investigation plan
ILCR	incremental lifetime cancer risk
ILM	EPA CLP's prefix designation for the inorganic metals analysis statement of work for EPA contract laboratory program
IM	interim measure; isobutyl methacrylate
IMU	inertial measurement unit
IM-AE	isobutyl methacrylate polymer AE
IMPA	isopropylmethyl phosphonic acid
in.	inch
Inc.	Incorporated
Ing	ingestion
Inh	inhalation
INT	interface
IOU	integrator operable unit
IP	ionization potential
IPS	International Pipe Standard
IR	ingestion rate
IRAO	interim remedial action objective
IRDMIS	Installation Restoration Data Management Information System
IR <sub>f</sub>	fish ingestion rate
'IR <sub>sw</sub>	ingestion rate
IRFNA	inhibited red fuming nitric acid
IRIS	Integrated Risk Information System
IROD	interim record of decision
IRP	Installation Restoration Program
IRSL	industrial regional screening level
IS	incremental sampling
ISAB	in situ anaerobic bioremediation
ISBN	International Standard Book Number
ISL	initial screening level
ISO	industry standard object
ISTD	in situ thermal destruction
ISTT	in situ thermal treatment
IT	IT Corporation
ITEMS	IT Environmental Management System™
ITRC	Interstate Technology and Regulatory Council
IV	intervention value
IVS	instrument verification strip
IW	installation-wide
IWGW	installation-wide groundwater
IWWP	installation-wide work plan
J	estimated concentration
J&E	Johnson and Ettinger
JD	jurisdictional determination
JOR	job order request
K	conductivity
KAPSDIDS	Kinetically Adjustable Pore Space Dilution Injection Delivery System

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
$K_d$	soil-water distribution coefficient
$K_{dbs}$	bed sediment-sediment pore water partition coefficient
KeV	kilo electron volt
kg	kilogram
$\text{kg/m}^3$	kilograms per cubic meter
$\text{KMnO}_4$	potassium permanganate
KO	Contracting Officer
$K_p$	permeability coefficient
$K_{oc}$	organic carbon partitioning coefficient
$K_{ow}$	octanol-water partition coefficient
kVA	kilovolt-ampere
L	if used as part of the units of measure, the acronym stands for "liter"; if used as a chemical name, this acronym stands for lewisite
$\text{L/cm}^3$	liters per cubic centimeter
$\text{L/day}$	liters per day
$\text{L/kg/day}$	liters per kilogram per day
LANL	Los Alamos National Laboratory
lb	pound
LBP	lead-based paint
lbs/year	pounds per year
LC	liquid chromatography
$\text{LC}_{50}$	lethal concentration for 50 percent population tested
LCS	laboratory control sample
LCS D	laboratory control sample duplicate
$\text{LD}_{50}$	lethal dose for 50 percent population tested
LDD	lost, damage, or destruction
LEL	lower explosive limit
LF	Leaching Factor
LGAC	liquid-phase granular activated carbon
LiDAR	Light Detection and Ranging
LL	low level
LLC	limited liability company
LNAPL	light nonaqueous-phase liquid
LOAEL	lowest-observed-adverse-effects level
LOD	limit of detection
LOEC	lowest-observable-effect-concentration
LOQ	limit of quantitation
LSA	limited site assessment
LSV	leachate screening value
LTM	long-term management
LTV	leachate threshold value
LUC	land-use control
LUCAP	land-use control assurance plan
LUCER	land-use control effectiveness report
LUCIP	land-use control implementation plan
m	meter
$\text{m/year}$	meters per year
$\text{m/yr}$	meters per year
$\text{m/second}$	meters per second
$\text{m}^3/\text{hour}$	cubic meters per hour
$\text{m}^3/\text{kg}$	cubic meters per kilogram
MACOM	Major Command
MADEP	Massachusetts Department of Environmental Protection
MADL	minimum analytical detection limit
MARB	Munitions Assessment Review Board
max	maximum
MB	method blank
MC	munitions constituents
MCDZ	McDonald Creek discharge zone
MCE	Maximum Credible Event
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MCPA	4-chloro-2-methylphenoxyacetic acid
MCP	2-(2-methyl-4-chlorophenoxy)propionic acid
MCS	media cleanup standard
MD	munitions debris; Mahalanobis Distance
MDAS	Material Documented as Safe
MDC	maximum detected concentration
MDCC	maximum detected constituent concentration
MDEH	Material Documented as an Explosive Hazard
MDL	method detection limit
MEC	munitions and explosives of concern
MEE	methane, ethane, and ethene
MEP	Multiple Extraction Procedure
MeV	mega electron volt
Mfp	Mississippian Fort Payne
mg	milligrams

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
mg/cm <sup>2</sup>	milligrams per square centimeter
mg/cm <sup>2</sup> /day	milligrams per square centimeter per day
mg/cm <sup>2</sup> /event	milligrams per square centimeter per event
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligram per kilogram per day
mg/kgbw/day	milligrams per kilogram of body weight per day
mg/L	milligrams per liter
mg/m <sup>3</sup>	milligrams per cubic meter
mgal	million gallons
MGFD	munition with the greatest fragmentation distance
mh	inorganic silts, micaceous or diatomaceous fine, sandy or silt soils
MHz	megahertz
MI	multi-incremental
MICC	Mission & Installation Contracting Command
min	minimum
MIMS	Munitions Information Management System
MINICAMS	miniature continuous air monitoring system
MIS	Management Information System
mL	milliliter
mm	millimeter
MMAAS	Mobile Munitions Assessment Systems
MMBTu/hr	million Btu per hour
MMCS	Missile and Munitions Command School
MM-CX	Military Munitions Center of Expertise
MMRP	Military Munitions Response Program
Mn <sup>+4</sup>	manganese
MNA	monitored natural attenuation
MnO <sub>4</sub> <sup>-</sup>	permanganate ion
MNR	monitored natural recovery
MOA	Memorandum of Agreement
MOCA	4,4-methylene-bis(2-chloroaniline)
MOGAS	motor vehicle gasoline
MOUT	Military Operations in Urban Terrain
MP	Military Police
MPA	methyl phosphonic acid
MPC	maximum permissible concentration; measurement performance criteria
MPM	most probable munition
MPPEH	Material Potentially Presenting an Explosive Hazard
MPR	4.2-Inch Mortar Proofing Range
SQL	method quantitation limit
MQO	measurement quality objective
MR	molasses residue; munitions response
MRA	munitions response area
MRC	multiple round container
MRL	method reporting limit
MRL	minimal risk level
MRR	Materials Receiving Report
MRS	Munitions Response Site
MRSP	Munitions Response Site Prioritization Protocol
MS	matrix spike
mS/cm	millisiemens per centimeter
mS/m	millisiemens per meter
MS/MSD	matrix spike/matrix spike duplicate
MSD	when discussing laboratory QC, MSD means matrix spike duplicate; when discussing explosives, MSD means minimum separation distance
MSFC	George C. Marshall Space Flight Center
msl	mean sea level
Mt	Mississippian Tuscomb Limestone
MTBE	methyl tertiary butyl ether
M&TE	measurement and test equipment
mV	millivolts
MW	monitoring well
Na	sodium
N/A	not applicable
NA	not applicable
NAD	North American Datum
NAD83	North American Datum of 1983
NaMnO <sub>4</sub>	sodium permanganate
NAPL	nonaqueous-phase liquid
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NAVD 88	North American Vertical Datum, 1988 adjustment
NAVD88	North American Vertical Datum of 1988
NB	nitrobenzene
NBA	Northern Burial Area
NCEA	National Center for Environmental Assessment

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
NCP	National Contingency Plan
NCR	nonconformance report
NCRP	National Council on Radiation Protection and Measurements
ND	not detected
NDA	Northern Disposal Area
NDMA	n-nitrosodimethylamine
NDPA	n-nitroso-di-n-propylamine
NE	northeast
NELAP	National Environmental Laboratory Accreditation Program
NEPA	National Environmental Protection Act
NEW	net explosive weight
NFA	no further action
NFG	National Functional Guidelines
NFPA	National Fire Protection Agency
NG	National Guard
ng/L	nanograms per liter
NGB	National Guard Bureau
NGP	National Guardsperson
NGVD	National Geodetic Vertical Datum
Ni	nickel
NIC	notice of intended change
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NJDEP	New Jersey Department of Protection
NLM	National Library of Medicine
NLT	no later than
NMEA	National Marine Electronics Association
No.	number
NO <sub>3</sub> <sup>-</sup>	nitrate
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effects level
NOEC	no-observable-effect concentration
NONEL	non-electric
NP	nitropropyl
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPW	net present worth
NR	not requested
NRC	National Research Council
NRCC	National Research Council of Canada
NRHP	National Register of Historic Places
NRL	Naval Research Laboratory
NRT	near real time
ns	nanosecond
NS	not surveyed
N-S	north to south
NSA	New South Associates, Inc.
NT	nitrotoluene
nT	nanotesla
nT/m	nanoteslas per meter
NTCRA	Non-Time Critical Removal Action
NTIS	National Technical Information Service
NTU	nephelometric turbidity unit
nv	not validated
NY DOH	New York State Department of Health
O&G	oil and grease
O&M	operation and maintenance
O <sub>2</sub>	oxygen
O <sub>3</sub>	ozone
OB/OD	open burn/open detonation
OBL	obligate
OCDD	octachlorodibenzo-p-dioxin
OD	outside diameter; other (nonmunitions) debris
OE	ordnance and explosives
OEC	Ordnance Explosives Center
OEHA	Office of Environmental Health Hazard Assessment (of the California Environmental Protection Agency)
OESS	Ordnance and Explosives Safety Specialist
OGMS	Ordnance Guided Missile School
oh	organic clays of medium to high plasticity
OH·	hydroxyl radical
ol	organic silts and organic silty clays of low plasticity
OMEMS	Ordnance Munitions and Electronic Maintenance School
OP	organophosphorus; organochlorine pesticide
ORA	Operational Range Assessment
ORAP	Operational Range Assessment Program
Ord	Ordovician
ORP	oxidation-reduction potential

## List of Abbreviations and Acronyms

### Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
OSA	Open Storage Area
OSD	overage/shortage/damage
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
OVA	organic vapor analyzer
OVB	overburden
OVB-S	shallow overburden
OVM	organic vapor monitoring
OVM-PID/FID	organic vapor meter-photoionization detector/flame ionization detector
OVS	oil/water separator
oz	ounce
P&T	pump and treat
PA	preliminary assessment
PA3	Plant Area 3, Incineraries Manufacturing
PAED	Public Access Exclusion Distance
PAH	polynuclear aromatic hydrocarbon
PAL	preliminary action level
PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
Parsons	Parsons Engineering Science, Inc.
Pb	lead
PBAA	polybutadiene acrylic acid
PBAN	polybutadiene/acrylic acid/acrylonitrile
PBC	performance-based contract
PBMS	performance-based measurement system
PC	permeability coefficient
PCA	tetrachloroethane
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
PCE	tetrachloroethene
PCHL	2,3,4,5,6-pentachlorocyclohexanol
PCMIA	Personal Computer Memory Card International Association
PCP	pentachlorophenol
PCR	polymerase chain reaction
PCWM	Potential Chemical Warfare Materiel
PDA	Personal Digital Assistant
PDB	polyethylene diffusive bag sampler
PDF	Portable Document Format
PDS	Personnel Decontamination System
PDT	Project Delivery Team
PEC	probable effect concentration
PEF	particulate emission factor
PEL	permissible exposure limit
PELA	P. E. LaMoreaux and Associates, Inc.
PERA	preliminary ecological risk assessment
PERC	perchloroethene
PES	potential explosive site
Pest.	pesticides
PETN	pentaerythritol tetranitrate
PFO	palustrine forested wetland
PFT	portable flamethrower
PG	professional geologist
pg/g	picograms per gram
PgM	program manager
pH	measure of acidity/alkalinity; hydrogen ion activity (negative of the logarithm, base 10)
PHC	principal hazardous constituent
PID	photoionization detector
PIEZ	piezometer
PINS	portable isotopic neutron microscopy
PK	packer
PLS	Professional Land Surveyor
PLS	Professional (licensed) Land Surveyor
PM	project manager
PMC	Program Management Contract
PNMSCM	Product Manager for Non-Stockpile Chemical Materiel
PMP	Project Management Plan
PMTP	Program Management Team Plan
POC	point of contact
POL	petroleum, oils, and lubricants
POTW	publicly owned treatment works
POW	prisoner of war; palustrine open water
Powell	John Powell Chemical Company
PP	Proposed Plan
ppb	parts per billion
ppbv	parts per billion by volume
PPE	personal protective equipment

## List of Abbreviations and Acronyms Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
ppm	parts per million
PPMP	Print Plant Motor Pool
PPRTV	provisional peer-reviewed toxicity values
ppt	parts per trillion
ppT	parts per thousand
PQL	practical quantitation limit
PR	potential risk
PRA	preliminary risk assessment
PRE	preliminary risk evaluation
PRG	preliminary remediation goal
PRO	petroleum range organics
PS	chloropicrin
PSA	potential source area
PSL	preliminary screening level
PSS	palustrine scrub shrub
PSSC	potential site-specific chemical
PSV	preliminary screening value
pt	peat or other highly organic silts
PT1	an incendiary mixture in munitions
PTFE	Polytetrafluoroethylene (Teflon)
PTMP	program team management plan
PTSM	principal threat source material
PVC	polyvinyl chloride
PWS	performance work statement
PZ	piezometer
QA	quality assurance
QA/QC	quality assurance/quality control
QAM	quality assurance manual
QAO	quality assurance officer
QAPP	quality assurance project plan
QASAS	Quality Assurance Specialist Ammunition Surveillance
QASP	Quality Assurance Surveillance Plan
QC	quality control
QCP	quality control plan
QCSM	Quality Control Site Manager
QCSR	quality control summary report
Q-D	quantity-distance
QL	quantitation limit
QP	Qualified Person
Q-Q	quantile-quantile
QSAR	quantitative structure-activity relationship
QSM	quality systems manual
QST	QST Environmental, Inc.
qty	quantity
Qual	qualifier
QuickSilver	QuickSilver Analytics, Inc.
R	when used as a validation qualifier, R means rejected; when used as a lab qualifier, R means resample; when used in text, R means retardation factor
R&A	relevant and appropriate
R <sup>2</sup>	coefficient of determination
RA	remedial action
RA(O)	remedial action (operations)
RAO	remedial action objective
RAP	recommended action plan
RAR	remedial action report
RARE	Redstone Arsenal Rocket Engine
RAWP	remedial action work plan
Raytheon	Raytheon Company
RBA	relative bioavailability
RBC	risk-based concentration
RBP	Rapid Bioassessment Protocol
RBRG	risk-based remedial goal
RBSC	risk-based screening concentration
RBSC <sub>i</sub>	risk-based screening concentration for industrial soil
RBSC <sub>R</sub>	risk-based screening concentration for residential soil
RBSC <sub>T</sub>	risk-based screening concentration for tap water
RBTL	risk-based target level
RBTL <sub>COC</sub>	risk-based target level for a given relevant COC, receptor, and source medium
RC	representative concentration; response complete
RC <sub>COC</sub>	representative concentration of the relevant COC in the given medium
RCA	root cause analysis
RCMD	Recovered Chemical Materiel Directorate
RCRA	Resource Conservation and Recovery Act
RCRA CA	Resource Conservation and Recovery Act Corrective Action
RCVM	Recovered Chemical Warfare Materiel
RD	remedial design
RDECOM	U.S. Army Research, Development, and Engineering Command



## List of Abbreviations and Acronyms

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Acronym	Definition
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine; cyclotrimethylenetrinitramine; 1,3,5-trinitro-1,3,5-triazine (cyclonite); Royal Demolition Explosive
REG	regular field sample
REL	recommended exposure limit; reference exposure level
RER	Record of Environmental Review
Rev	Revision
RF	response factor
RFA	request for analysis
RfC	reference concentration
RfD	reference dose
RFI	RCRA facility investigation
RFQ	request for quotation
RG	remedial goal
RGO	remedial goal option
RI	remedial investigation
RIP	remedy in place
RL	reporting limit
RM	risk management
RM-1	Risk Management-1
RM-2	Risk Management 2
RME	reasonable maximum exposure
RMP	risk management plan
Ro	Robertsville silt loam
ROD	Record of Decision
ROF	report of findings
ROI	radius of influence
ROP	Redstone Ordnance Plant
ROPS	roll over protection system
RPD	relative percent difference
RR	range residue
RRF	relative response factor
RRSE	Relative Risk Site Evaluation
RRSL	residential regional screening level
RS	prefix for groundwater monitoring well at Redstone Arsenal
RSA	Redstone Arsenal
RSD	relative standard deviation
RSL	Regional Screening Level
RSP	Redstone Arsenal spring
RTAP	Real-Time Analytical Platform
RTC	Redstone Test Center
RTECS	Registry of Toxic Effects of Chemical Substances
RTK	real-time kinematic
RTO	regenerative thermal oxidizer
RTOP	Request for Task Order Proposal
RTS	robotic total station
RTTC	Redstone Technical Test Center
Rust	Rust Environment and Infrastructure, Inc.
s/n	signal-to-noise ratio
SA	exposed skin surface area; source area
SAA	satellite accumulation area
SAC	site access control
SACIMS	Site Access Control Information Management System
SACP	Site Access Control Plan
SAD	South Atlantic Division
SAE	Society of Automotive Engineers
SAIC	Science Applications International Corporation
SAP	sampling and analysis plan
SAR	structure-activity relationship
SARA	Superfund Amendments and Reauthorization Act
SB	soil boring
SC	specific conductance
SCG	storage compatibility group
SCBA	self-contained breathing apparatus
Sch.	schedule
SCM	site conceptual model
SD	sediment
SDG	sample delivery group
SDS	safety data sheet
SDSW	sediment/surface water
SDWA	Safe Drinking Water Act
SDZ	surface danger zone
SED	Software Engineering Directorate
SEE	steam enhanced extraction
SF	cancer slope factor
SFSP	site-specific field sampling plan
SGF	standard grade fuels
Shaw	Shaw Environmental, Inc.
SHP	safety and health plan

## List of Abbreviations and Acronyms Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
SI	site inspection
Sil	Silurian
SIM	Selective Ion Monitoring
SIR	secondary investigation report
SL	standing liquid
SLERA	screening-level ecological risk assessment
SM	sulfur monochloride
SMDP	Scientific Management Decision Point
SMF	smoke munitions filling
SMF 3	Smoke Munitions Filling Plant 3
SMP	site management plan
SNR	signal-to-noise ratio
SO <sub>4</sub>	sulfate
SOD	soil oxidant demand
SOP	standard operating procedure
SOPP	standard operating project procedure
SP	submersible pump
SPA	single point anomaly
SPCC	system performance calibration compound
SPCS	State Plane Coordinate System
SPLP	synthetic precipitation leaching procedure
SPM	sample planning module
SPRG	spring
SQG	sediment quality guideline
SQRT	screening quick reference tables
SRA	streamlined human health risk assessment; saturated response area
SRB	sulfate-reducing bacteria
SRI	supplemental remedial investigation
SRM	standard reference material
SS	surface soil
SSC	site-specific chemical
SSHO	site safety and health officer
SSHP	site-specific safety and health plan
SSL	soil screening level
SSSL	site-specific screening level
SSTL	site-specific target level
SSPA	site-specific probability assessment
STB	supertropical bleach
STC	source-term concentration
STD	standard deviation
Std. units	standard units
STEL	short-term exposure limit
STP	sewage treatment plant
STL	Severn-Trent Laboratories
STT	sludge thickener tank
SU	sampling unit when used in a grid for incremental sampling; when used as a unit for pH, this acronym stands for standard unit
SUXOS	senior UXO supervisor
SV	screening value
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SW-846	U.S. EPA's <i>Test Methods for Evaluating Solid Waste: Physical/Chemical Methods</i>
SW	surface water
SWCC	State of Alabama Soil and Water Conservation Committee
SWMU	solid waste management unit
SWTR	surface water
SZ	support zone
TA	test area
TAL	target analyte list
TAT	turn around time
TB	trip blank
TBC	to be considered
TBD	to be determined
TCA	trichloroethane
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	tetrachlorodibenzofurans
TCE	trichloroethene
TCH	thermal conductive heating
TCL	target compound list
TCLP	toxicity characteristic leaching procedure
TCMX	tetrachloro-m-xylene
TCRA	time critical removal action
TDGCL	thiodiglycol
TDGCLA	thiodiglycol chloroacetic acid
TDS	total dissolved solids
TEA	triethylaluminum
TEC	threshold effect concentration
TeCA	1,1,2,2-tetrachloroethane

# List of Abbreviations and Acronyms

## Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
TEMP	temperature
TEMTADS	Time-Domain Electromagnetic Multisensor Tower Array Detection System
TEQ	toxic equivalency quotient
TERC	Total Environmental Restoration Contract
Tetryl	trinitrophenyl/methylnitramine
TEU	Technical Escort Unit
THI	target hazard index
Thiokol	Thiokol Corporation
TIC	tentatively identified compound
TIR	thermal infrared survey
TLV	threshold limit value
TM	Technical Manual
TMP	temperature measuring point
TMPW	temporary groundwater monitoring well
TN	Tennessee
TNB	trinitrobenzene
TNT	trinitrotoluene
TO	task order
TOC	use top of casing when defining the well depth; use total organic carbon when defining a general chemistry parameter
TOI	target of interest
TOW	tube-launched, optically-tracked, wire-guided missile
TP	Technical Paper
TPH	total petroleum hydrocarbon
TPI	three-phase inspection
TPP	Technical Project Planning
TR	target cancer risk
TRADOC	U.S. Army Training and Doctrine Command
TRPH	total recoverable petroleum hydrocarbons
TRS	TRS Group Inc.
TRV	toxicity reference value
TSA	temporary storage area
TSCA	Toxic Substances Control Act
TSCRN	top of screen
TSDf	treatment, storage, and disposal facility
TSLC	target soil leachate concentration
TSS	total suspended solids
TTAP	treatment system tap (port)
TTZ	target treatment zone
Tu	Tupelo silt loam
TVA	Tennessee Valley Authority
TWA	time-weighted average
TXDOT	Texas Department of Transportation
TX-3	small rocket motor used for ballistics testing
U	not detected above reporting limit
U.S.	United States (of America)
UB	potential blank contamination
UCL	upper confidence limit
UCR	upper certified range
UDMH	unsymmetrical dimethyl hydrazine
UF	uncertainty factor
UFP	Uniform Federal Policy
UIC	underground injection control
UJ	not detected, estimated due to data validation anomaly
UNEP	United Nations Environment Program
UPL	upper prediction limit; upland
UR	not detected; rejected due to data validation anomaly
URF	unit risk factor
USACE	U.S. Army Corps of Engineers
USACMLS	U.S. Army Chemical School
USAEC	U.S. Army Environmental Command
USAHA	U.S. Army Environmental Hygiene Agency
USAESCH	U.S. Army Engineering Support Center, Huntsville
USAMPS	U.S. Army Military Police School
USAPHC	U.S. Army Public Health Command
USATCES	U.S. Army Technical Center for Explosive Safety
USATEU	U.S. Army Technical Escort Unit
USATHAMA	U.S. Army Toxic and Hazardous Material Agency
USC	United States Code
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
UTL	upper tolerance limit
UTM	Universal Transverse Mercator
UTS	universal treatment standard

## List of Abbreviations and Acronyms Redstone Arsenal, Madison County, Alabama

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Acronym	Definition
UTV	utility terrain vehicle
UXO	unexploded ordnance
UXOSP	unexploded ordnance sweep personnel
UXOQCS	UXO Quality Control Supervisor
UXOSO	UXO safety officer
V	vanadium
VC	vinyl chloride
VGIC	liquid-phase granular activated carbon
VI	vapor intrusion
VISL	vapor intrusion screening level
VOA	volatile organic analyte
VOC	volatile organic compound
VOH	volatile organic hydrocarbon
VP	soil vapor point
VQ	validation qualifier
vs	versus
VSI	visual site inspection
VSL	vapor screening level
VSP	Visual Sample Plan
VX	nerve agent (O-ethyl-S-[diisopropylaminoethyl]-methylphosphonothiolate)
WAC	Women's Army Corps
WDTA	Waste Disposal Trench Area
WNWR	Wheeler National Wildlife Refuge
WOE	weight of evidence
WP	white phosphorus
WPL	worker population limit
WQC	water quality criteria
WRS	Wilcoxon rank sum
WS	watershed
WSA	Watershed Screening Assessment
WTP	water treatment plant
WWI	World War I
WWII	World War II
WWTP	wastewater treatment plant
X	Data collected in a manner that is now considered to be inconsistent with good scientific practice. These data are considered unusable. However, since these data exist in the database, additional definitive samples may be needed to verify the presence or absence of any positively detected result.
XRF	x-ray fluorescence
yd <sup>3</sup>	cubic yards
ZVI	zero-valent iron

**ATTACHMENT 2**

**FIELD RECORDS**  
**(DIGITAL DELIVERY ON DVD)**

## **ATTACHMENT 2**

### **FIELD RECORDS**

This attachment presents available field records which support Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) reports for groundwater units at Redstone Arsenal (RSA). These records comprise a comprehensive reference for the entire facility, as of December 12, 2017, and are organized in folders as follows.

#### **Monitoring Wells**

This folder contains a subfolder for each groundwater monitoring well installed by the Army, as well as some wells installed by the National Aeronautics and Space Administration (NASA).

The subfolder for each well contains the following records, where available:

- Boring log(s), including monitoring well construction logs
- Well development logs
- Groundwater sample collection logs (filename includes sample date in six-digit format)
- Abandonment (closure) logs.

#### **Piezometers, Vapor Points, and FLUTe Borings**

This folder contains a file for each direct-push technology (DPT) boring, including piezometers, vapor points, and boreholes advanced for FLUTe® NAPL liner testing. The file for each boring contains the following records, as applicable:

- Boring log(s)
- Piezometer construction logs
- Sample collection logs for groundwater and/or soil vapor.

#### **Springs**

This folder contains a file for each spring sample or spring sampling event. Each file contains sample collection logs for the media sampled at the spring, including groundwater, surface water, and sediment, as applicable. Typically, the filename includes the sample date in six-digit format, although some include the month and year of a sampling event that includes multiple springs.

**Surface Water and Sediment Locations**

This folder contains records for other locations where surface water and/or sediment were sampled recently, excluding spring locations. Each file contains sample collection logs for surface water and/or sediment, as applicable. Typically, the filename includes the sample date in six-digit format, although some include the month and year of a sampling event that includes multiple locations.

## **TABLES**



SWMU or AOC <sup>(1)</sup>	Site Name <sup>(1)</sup>	Location			General Site Status Information <sup>(8)</sup>			
		Groundwater Unit	Within MSFC	Within MSFC OU-3	Site Status	RFI Status	RFI Approval Status	Cur
<b>MSFC-002/087</b>	Inactive Abandoned Drum Disposal Site/Inactive Cyanide Lagoon	RSA-149	Yes	Yes	Inactive	NFA	NFA	
<b>MSFC-003</b>	Inactive Old Bone Yard Disposal Site #1	RSA-149	Yes	Yes	Active	Rev 0	RFI in progress	Fieldwork underway. An IM i RFI. The Army is developing Rev 0 RFI scheduled for subm approved schedule extension
<b>MSFC-027</b>	Inactive (M-1) Waste Accumulation Area	RSA-149	Partially	Yes	Active	Complete	Approved	Rev 1 RFI Report submitted to concurrence on Rev 1 RFI Rep concurrence on the CMIP (so Modification 10 dated 2/15/1
<b>MSFC-034</b>	Sump in the North Central Part of Bldg 4481	RSA-149	Yes	Yes	Active	Rev 0	RFI in progress	RFI WP submitted 11/22/16. Rev 0 RFI report scheduled for comment letter of approved
<b>MSFC-035</b>	Inactive Sump/Tiled Drain Field - East TA	RSA-148	Yes	Yes	Active	Rev 0	RFI in progress	Phase Ib Intrusive Investigative MWs planned). RFI fieldwork submission on 12/10/18 per 6/17/16.
<b>MSFC-052e</b>	Portion of Industrial Sewer East of MSFC Property	RSA-148	No	Yes	Inactive	NFA	NFA	SMWU integrated into RSA-1
<b>MSFC-053</b>	Former Propellant Storage Area and Test Stand Site	RSA-149	Yes	Yes	Active	Complete	Approved	RFI Completed. Received AD recommending NFA for soils/their letter dated 10/1/14.
<b>MSFC-055</b>	Dismantled Stauffer Chemical Mfg Plant	RSA-149	Yes	Yes	Inactive	NFA	NFA	NFA site.
<b>MSFC-060</b>	Drainage System for Historic Redstone Test Site	RSA-149	Yes	Yes	Inactive	NFA	NFA	NFA site.
<b>MSFC-065</b>	1800-ft Surface Drainage Ditch/Area	RSA-149	Yes	Yes	Inactive	NFA	NFA	NFA site.

SWMU or AOC <sup>(1)</sup>	Site Name <sup>(1)</sup>	Location			General Site Status Information <sup>(8)</sup>			
		Groundwater Unit	Within MSFC	Within MSFC OU-3	Site Status	RFI Status	RFI Approval Status	Cur
<b>MSFC-D</b>	Containment Area for Tanks 4234 A, B & C	RSA-149	Yes	Yes	Inactive	NFA	NFA	NFA site.
<b>RSA-009</b>	Inactive Sewage Treatment Plant #3	RSA-149	No	Yes	Active	Complete	Approved	Rev 2 RFI Report revised and Received ADEM concurrence but not contracted.
<b>RSA-010</b>	Closed Sanitary Landfill	RSA-148	No	Yes	Active	Rev 1	RFI in progress	Rev 0 RFI Report submitted 1 scheduled for submission on letter of approved schedule & Contracting realignment req
<b>RSA-028</b>	In-ground Oil/Water Separator, 5693 Area	RSA-148	No	No	Active	Rev 3	RFI in progress	Rev 2 RFI Report submitted to comments dated 10/5/15, Re under contract. Extension rec submittal scheduled for 4/15
<b>RSA-030</b>	Former Central Oil/Water Separator	RSA-147	No	No	Active	Complete	Approved	Rev 1 RFI Report submitted to concurrence received on 5/4, submission on 10/2/18 per A 6/15/17.
<b>RSA-031</b>	Former Central Oil/Water Separator Storage Tanks	RSA-147	No	No	Active	Complete	Approved	Rev 1 RFI Report submitted to concurrence received on 5/4,
<b>RSA-033</b>	Plating Room Floor Drains, Bldg 5432	RSA-147	No	No	Inactive	NFA	NFA	NFA site.
<b>RSA-043</b>	Underground Used Oil Storage Tank Bldg 5435A	RSA-147	No	No	Inactive	NFA	NFA	NFA site.
<b>RSA-044</b>	Underground Used Oil Storage Tank Bldg 5435B	RSA-147	No	No	Inactive	NFA	NFA	NFA site.
<b>RSA-049</b>	Capped Arsenic Waste Lagoons - West, Area F	RSA-148	No	No	Active	Complete	Legacy Approval	CMIP required for groundwat

SWMU or AOC <sup>(1)</sup>	Site Name <sup>(1)</sup>	Location			General Site Status Information <sup>(8)</sup>			
		Groundwater Unit	Within MSFC	Within MSFC OU-3	Site Status	RFI Status	RFI Approval Status	Cur
RSA-053 (includes Northern Disposal Area)	Inactive Sanitary & Industrial Landfill, Area Q3	RSA-148	No	Yes	Active	Complete	Legacy Approval	ADEM concurrence on the Final Groundwater investigation deferred to report submitted 2/6/16. AD the Army to proceed with LTI annual Effectiveness Report f
	Northern Disposal Area	RSA-148	No	Yes				Further delineation within th RSA-053 has been designated groundwater unit.
RSA-054	Inactive Sanitary & Industrial Landfill, Area T	RSA-147	No	No	Active	Complete	Legacy Approval	RFI completed in 1992-93 time CMI completed. Rev 0 Correction submitted on 28-Jan-15. LTM separately.
RSA-055	Inactive Sanitary & Industrial Landfill, Area S	RSA-147	No	No	Active	Complete	Legacy Approval	Coupled with RSA-054.
RSA-056	Closed Arsenic Waste Ponds (South) Area U	RSA-147	No	No	Active	Complete	Legacy Approval	CMIP required for soil and groundwater submission 10/2/17 per ADEM RSA submitted a schedule extension dated 11/30/2017 for those related to contracting realignment. / schedule extension on 4/6/20
RSA-057	Former Lewisite Drum Storage Yard, Area V	RSA-147	No	No	Active	Complete	Legacy Approval	Final Phase II RI completed in ADEM 9/6/07, focused on soil RI was sufficient to delineate soils are contributing to groundwater will be included as part of the for soil and groundwater remediation action has been completed a
								Rev 0 CMIP submitted 11/14,

SWMU or AOC <sup>(1)</sup>	Site Name <sup>(1)</sup>	Location			General Site Status Information <sup>(8)</sup>			
		Groundwater Unit	Within MSFC	Within MSFC OU-3	Site Status	RFI Status	RFI Approval Status	Cur
<b>RSA-063</b>	Inactive Chemical Munitions Disposal, Area M	RSA-149	No	No	Active	Deferred	-	IM required prior to completi
<b>RSA-072</b>	Mortar Shell Test Site, Area B; The bulk of this (range) site is in RSA-150 and is addressed in that RFI.	RSA-149/150	No	Partially	Active	Deferred	-	RFI deferred to Range Closur
<b>RSA-075</b>	Inactive Solid Waste Incinerator	RSA-147	No	No	Inactive	NFA	NFA	NFA site.
<b>RSA-101</b>	DDT Contaminated Area DO	RSA-147/148/149	No	Partially	Inactive	NA	-	Olin Consent Decree area.
<b>RSA-102</b>	DDT Plant Site Q-6	RSA-147	No	No	Inactive	NFA	NFA	Part of RSA-117.
<b>RSA-103</b>	DDT Settling Lagoon	RSA-147	No	No	Inactive	NFA	NFA	Part of RSA-117.
<b>RSA-104</b>	Inactive ISP Wastewater Discharge Ditch	RSA-147	No	No	Inactive	NFA	NFA	Part of RSA-117.
<b>RSA-105</b>	DDT Drainage Ditches	RSA-147	No	No	Inactive	NFA	NFA	Part of RSA-117.
<b>RSA-106</b>	DOD Earthen Dams	RSA-147	No	No	Inactive	NFA	NFA	Part of RSA-117.
<b>RSA-107</b>	Closed DDT Soil/Debris Landfill	RSA-148	No	Yes	Inactive	NFA	NFA	NFA site.
<b>RSA-109</b>	Former Chemical Munitions Staging Area	RSA-149	No	Yes	Active	Rev 0	RFI in progress	Rev 0 Phase II RFI WP submit to ADEM 7/14/17.
<b>RSA-114</b>	Inactive Madkin Mt Rock Quarry	RSA-147/148	No	No	Active	Deferred	-	IM required prior to completi RFI report scheduled for 12/2 completion of IM.
<b>RSA-117</b>	Former Liquid Caustic Mfg Plant, Area R	RSA-147	No	No	Active	Rev 1	RFI in progress	Rev 0 RFI report submitted 4, comments (1/19/17), a Rev 1 dated 7/7/17, the Army requ to be submitted 6/20/20, pro contaminated soil in the inter The IM work plan is propose

SWMU or AOC <sup>(1)</sup>	Site Name <sup>(1)</sup>	Location			General Site Status Information <sup>(8)</sup>			
		Groundwater Unit	Within MSFC	Within MSFC OU-3	Site Status	RFI Status	RFI Approval Status	Cur
<b>RSA-124</b>	Dismantled Calgon DDT Contaminated Water Treatment Plant	RSA-147	No	No	Inactive	NFA	NFA	
<b>RSA-125</b>	Satellite Waste Accumulation Area, Bldg 5477	RSA-147	No	No	Inactive	NFA	NFA	
<b>RSA-126</b>	Inactive Open Burn Trench, Area U	RSA-147	No	No	Active	Rev 1	RFI in progress	Rev 0 RFI Report submitted to report submitted to ADEM 5/ based on ADEM's comments submission 8/11/16.
<b>RSA-127</b>	Photo Lab Process Wastewater Sump Bldg 5451	RSA-147	No	No	Inactive	NFA	NFA	
<b>RSA-139</b>	Closed Arsenic Waste Pond (North) Area U	RSA-147	No	No	Active	Complete	Legacy Approval	Coupled with RSA-056.
<b>RSA-141</b>	4.2-inch Mortar Disposal Site, Bldg 4656	RSA-148/149	Yes	Yes	Active	Complete	Approved	Rev 0 RFI report submitted 4, RFI Report submitted to ADEM concurrence on Rev 1 RFI on
<b>RSA-183</b>	Former Lewisite Manufacturing Lines 1 & 2	RSA-148	No	Partially	Active	Complete	Legacy Approval	ADEM concurrence on the Fi
<b>RSA-216</b>	Laboratory Injection Test Facility, Bldg 5475	RSA-147	No	No	Active	Rev 0	In review	Rev 0 RFI Report submitted 7
<b>RSA-222</b>	Roads and Grounds Maintenance Shop, Bldg 5494	RSA-148	No	No	Active	Complete	Approved	Rev 1 RFI Report submitted to concurrence letter dated 12/
<b>RSA-223</b>	Central Railroad Classification Yard	RSA-147	No	No	Inactive	NFA	NFA	
<b>RSA-224</b>	Container Storage Area	RSA-147	No	No	Inactive	NFA	NFA	Investigation completed; Rec in Permit Modification 001 tc
<b>RSA-225</b>	Fuse Modification Line 7	RSA-147	No	No	Active	Complete	Approved	Rev 1 RFI Report submitted to ADEM 8/4/16. CMIP require

SWMU or AOC <sup>(1)</sup>	Site Name <sup>(1)</sup>	Location			General Site Status Information <sup>(8)</sup>			
		Groundwater Unit	Within MSFC	Within MSFC OU-3	Site Status	RFI Status	RFI Approval Status	Current
<b>RSA-240</b>	Substation No.7, Formerly Bldg 5290 (demolished)	RSA-147	No	No	Active	Complete	Approved	Rev 0 RFI Report submitted to ADEM on 8/29/14. ADEM concurred 10/28/15. Moved to Table VI
<b>RSA-249</b>	Inactive Old Bone Yard Disposal Site 2	RSA-148	No	No	Active	Rev 0	RFI in progress	Rev 0 RFI completed. Submit for expiration.
<b>RSA-250</b>	Former Storage Warehouse, Bldg 778/5678	RSA-148	No	No	Active	Complete	Approved	Rev 1 RFI Report submitted to ADEM for concurrence letter dated 9/11/13/16 (slip sheets submitted for excavation) has been complete
<b>RSA-251</b>	Former Phosgene Plant	RSA-148	No	No	Inactive	NFA	NFA	
<b>RSA-252</b>	Incendiary Bomb Facility Plant 2 Area	RSA-148	No	No	Active	Complete	Approved	Rev 2 RFI Report submitted to ADEM for concurrence letter dated 11/17/15 and groundwater (RSA-252).
<b>RSA-264</b>	RR Spring	RSA-149	No	Partially	Active	Rev 1	RFI in progress	Rev 1 Site Characterization Plan (slip sheets submitted 11/18/17 for review in April 2017.
<b>RSA-270</b>	Hazardous Waste TSA & Recycling Facility Bldg 5423	RSA-147	No	No	Inactive	NFA	NFA	
<b>RSA-277</b>	Bldg 5487, Wastewater Maintenance Shop Acid Bath Wash Down Area	RSA-147	No	No	Active	Complete	Approved	Rev 2 RFI Report submitted to ADEM's concurrence on the RFI 4/17/15.
<b>RSA-279</b>	Smoke Grenade Area	RSA-147	No	No	Inactive	NFA	NFA	Part of MMRP SI. ADEM concurrence letter dated March 12, 2009.
<b>RSA-285</b>	Former WP Grenade Test Area	RSA-149	Yes	Yes	Inactive	NFA	NFA	
<b>RSA-290</b>	Drinking WTP#3, Sludge Thickener & Drying Beds, Bldgs 5431 & 5433	RSA-147	No	No	Active	Rev 1	In review	Rev 0 RFI Report submitted 11/4/12/17.

SWMU or AOC <sup>(1)</sup>	Site Name <sup>(1)</sup>	Location			General Site Status Information <sup>(8)</sup>			
		Groundwater Unit	Within MSFC	Within MSFC OU-3	Site Status	RFI Status	RFI Approval Status	Cur
<b>RSA-E</b>	No. 2 Fuel Oil Spill, Tank 5693 at the Fuel Farm	RSA-148	No	Partially	Active	Rev 3	RFI in progress	Rev 3 RFI Report submitted to
<b>RSA-F</b>	Fenced Open Storage/Laydown Yard	RSA-147	No	No	Active	Rev 2	RFI in progress; approval pending	Rev 1 RFI Report submitted 9/2/17. Rev 2 RFI in Army n

<sup>(1)</sup> Per Table VI.1 of the RCRA Permit (Mod 10, February 2017), Master List of SWMUs and AOCs.

<sup>(2)</sup> Per Table VI.2 of the RCRA Permit Mod 10, February 2017), SWMUs/AOCs Requiring RCRA Facility Investigation.

<sup>(3)</sup> Per Table VI.3 of the RCRA Permit (Mod 10, February 2017), unless otherwise noted.

<sup>(4)</sup> Per Table VI.5 of the RCRA Permit (Mod 10, February 2017), SWMUs/AOCs Requiring Interim Measure(s) and/or Source Removal.

<sup>(5)</sup> Per Table VI.6 of the RCRA Permit (Mod 10, February 2017), SWMUs/AOCs Requiring a Corrective Measure(s) Implementation Plan.

<sup>(6)</sup> Per Table VII.2 of the RCRA Permit (Mod 10, February 2017), Groundwater Quality Monitoring Constituents.

<sup>(7)</sup> Per Table VIII.1 of the RCRA Permit (Mod 10, February 2017), SWMUs/AOCs Requiring Corrective Measures.

<sup>(8)</sup> Status as of April 2017.

ADEM - Alabama Department of Environmental Management

AOC - Area of concern.

BHHRA - Baseline human health risk assessment.

CMI - Corrective measures implementation.

CMIP - Corrective measures implementation work plan.

COC - Chemical of concern.

DD - Decision document.

FFA - Federal Facilities Agreement.

IM - Interim measure.

LTM - Long-term monitoring.

MMRP - Military Munitions Response Program.

MSFC - George C. Marshall Space Flight Center.

MW - Monitoring well

NASA - National Aeronautics and Space Administration.

NFA - No further action

OU - Operable unit.

PCB - Polychlorinated biphenyl.

POP - Period of performance.

RAP - Remedial action plan

RCRA - Resource Conservation and Recovery Act

RFI - RCRA facility investigation.

RI - Remedial investigation.

ROD - Record of decision.

RSA - Redstone Arsenal.

SB - Statement of basis.

SI - Site investigation.

SLERA - Screening-level ecological risk assessment

SWMU - Solid waste management unit.

WP - Work plan.

Table 1-2

**Summary of NASA MSFC Groundwater Plumes and Source Areas**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 1 of 4)

Plume	Source Areas <sup>a</sup>	Source Area Description <sup>a</sup>
Northeast Plume	SA-9 (MSFC-092)	<b>Building 4435 - Former Taxi and Bus Refueling Area.</b> Consisted of an oil and grease storage building, fuel pump island with associated USTs, and a vehicle wash rack.
	SA-10 (MSFC-093)	<b>Building 4487 - Sump Area.</b> Sump area between B and C wings of Building 4487. Sump houses steam lines and a diesel-powered generator. NASA personnel indicate the sump may have been a former acid neutralization basin.
	SA-14 (MSFC-034) <sup>b</sup>	<b>Building 4481 - North Parking Area.</b> Contains an inactive sump that was used to decontaminate "wild" batches of mustard with DANC.
Northwest Plume	SA-11 (MSFC-088)	<b>Building 4760 - Surface Treatment Facility.</b> The building housed the IWTF, along with metal plating and surface finishing operations. The plating area also contains two PCE vapor degreasers. A 22,000-gallon sump in the basement receives wastewaters from the plating operations.
	SA-12 (MSFC-094)	<b>Building 4705 - West Clean Room.</b> A 500-gallon TCE tank and 12,000 gallon deionized water tank are located on the western side of Building 4705. Both TCE and PCE have been used in the tube cleaning area located in the western part of Building 4705 since its construction in 1960. The current solvent storage and recovery room was formerly the TCE room, which contained two TCE tanks and associated pumps for circulation. Both the tube cleaning room area and the former TCE room have floor drains that probably received incidental spills and other discharges of solvents. Floor drains in the two areas discharge to a sump located in Room E-8 on the western side of Building 4705. The sump discharges to the former industrial sewer on the western side of the building. From 1960 to 1986, condensate from a fume hood over the PCE vapor degreaser was piped to an underground condensate cooling pit located on the western side of Building 4705. Overflow from the condensate pit discharged to the storm sewer on the western side of the building.
	SA-13 (MSFC-094)	<b>Building 4705 - North Satellite Accumulation Area.</b> The SA is located on the northern side of Building 4705. An abandoned paint shop (Building 4703) located in this area was used by the Department of the Army (DA) to paint missiles assembled in Buildings 4705 and 4706. TCE probably was used to clean the missiles before they were painted in the booth. Neither the drum storage unit nor the paint booth is now in use.



Table 1-2

**Summary of NASA MSFC Groundwater Plumes and Source Areas**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 2 of 4)

Plume	Source Areas <sup>a</sup>	Source Area Description <sup>a</sup>
Central Plume	SA-7 (MSFC-090)	<b>Building 4653 - Components Support Building.</b> The building currently contains machine shops, a high-pressure test facility for testing valves, and two degreasing rooms. TCE formerly was used for degreasing in the eastern wing of Building 4653. Two degreasing rooms were located in the central portion of the eastern wing. The degreasing rooms serviced the former turbo pump shop, which was located in the southern portion of the eastern wing, and the former valve laboratory, which was located in the central portion of the eastern wing. The northern portion of the eastern wing of Building 4653 was a former clean room and tube cleaning room. Both TCE and trichlorofluoromethane were used in the tube cleaning area, which was active until the early 1980s. Both degreasing rooms and the tube cleaning area formerly had floor drains which were connected to a sewer pipe that extends west from the eastern wing of the building and exits into an adjacent field west of the Building (RSA-141). According to contractor personnel, two sumps on the northern side of the building are associated with this pipe. TCE and other spent solvents were discharged from the degreasers and floor drains to the pipeline as a means of disposal.
	SA-8 (MSFC-091)	<b>Building 4638 - Maintenance Shop.</b> The building is a former maintenance shop and housed a solar-powered missile-grade air system. Building 4638 has a covered outdoor storage area on its southeastern corner. During the 1998 site inspection, the storage area was empty and no information could be obtained regarding the chemicals stored at the building. Ring-shaped rust stains on the concrete floor indicate that drums were stored there in the past. Other stains indicative of potential spills were also observed. the storage area has a concrete containment structure. A floor drain in the southeastern corner of the containment is connected to a PVC pipe that discharges to an adjacent drainage ditch.
	SA-15 (MSFC-031)	<b>Hazardous Waste Container Storage Area.</b> SA-15 is an area of soil and TCE contamination identified during the OU-13 investigation of MSFC-031, the temporary container storage area for hazardous wastes generated at MSFC. The waste storage facility has operated since 1985. The groundwater SA is on the northern side of Building 4640 in an area where drums historically were stored.

Table 1-2

**Summary of NASA MSFC Groundwater Plumes and Source Areas**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 3 of 4)

Plume	Source Areas <sup>a</sup>	Source Area Description <sup>a</sup>
Southeast Plume	SA-1 (MSFC-063)	<b>Building 4572 - Static Test Tower.</b> The DA originally constructed this test tower in 1954 as part of the Guided Missile Test Facility. It was later used by NASA for test firing liquid oxygen and Rocket Propellant (RP)-1 rocket engines. It was most heavily used by NASA in the 1960s. MSFC-063 is a drainage pathway south of Building 4572 that carried deluge water from the test tower to the Liquid Waste Disposal Reservoir (MSFC-009). This pipeline transfers water related to test stand activities at Buildings 4514 and 4572, which primarily included TCE. TCE was used at Building 4572 from 1954 to 1972 for rocket engine flushing and general cleaning. The TCE from engine flushing practices was discharged to the liquid waste disposal system, which included the drainage pathway (MSFC-063), the pipeline (MSFC-064), and ultimately, the liquid waste reservoir (MSFC-009) before flowing offsite to Huntsville Spring Branch.
	SA-2 (MSFC-005)	<b>Test Complex 300 Holding Pond.</b> The holding pond is approximately 40 feet by 40 feet in surface area and was constructed by NASA in 1963 as a waste-holding pond for TC-300 (Building 4530). According to NASA personnel, component parts were cleaned with TCE following testing at adjacent Building 4531, and TCE-contaminated water was formerly discharged to the pond. The amount of TCE used and discharged is unknown, however, NASA personnel indicate that TCE usage was minimal at TC-300 as compared to other test areas of the facility. No releases to the environment are known to have occurred since the early 1980s. Although not currently configured as such, the pond was originally constructed such that any pond overflows, if any were to occur, would do so via a spillway at the southwestern corner and discharge to the land surface in that area.
	SA-3 (MSFC-006)	<b>Building 4583 - Test and Data Recording Facility.</b> The facility was originally used by the DA, and then by NASA, for testing reduced scale model liquid oxygen and RP-1 rocket engines. Testing of the model engines was performed in small concrete test cells that were located both inside and outside of Building 4583. After each test, the model engines were flushed with TCE. Liquid wastes from testing activities, including TCE flush, waste rocket fuel, and deluge water, were discharged from the test cells to Pond 4586 (MFSC-006) by a system of concrete-lined drainage pathways. Overflow from the pond discharged to the south in a drainage pathway, and eventually flowed to the Liquid Waste Disposal Reservoir (MSFC-009). According to personnel, liquid waste flowed at hundreds of gallons per minute in the drainage pathways during periods of heavy testing in the 1960s and early 1970s.
	SA-4 (MSFC-003E)	<b>Landfill Near Water Tanks 4552 and 4562.</b> The source of contamination is landfilling operations. A 1956 aerial photograph shows the ground disturbances, and interviews with DA personnel indicate that two areas were used to bury primary debris from testing operations at Building 4572 (Static Test Tower) during the late 1950s.

Table 1-2

**Summary of NASA MSFC Groundwater Plumes and Source Areas  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 4 of 4)

Plume	Source Areas <sup>a</sup>	Source Area Description <sup>a</sup>
Southwest Plume	SA-5 (MSFC-082)	<b>Former Mustard Gas Demil Site.</b> Although SA-5 is collocated with MSFC-078, a laydown yard known as the Gillespie Flats Boneyard, NASA activities were not known to have contributed to the chlorinated volatile organic compound groundwater and soil contamination. The source of contamination is landfill operations by the DA in the 1950s. A 1956 aerial photograph shows ground disturbances, and interviews with DA personnel indicated that this area, along with the area associated with SA-4, was used to bury debris from testing operations at Building 4572 (Static Test Tower) during the late 1950s.
	SA-6 (MSFC-004)	<b>West Test Area Holding Pond.</b> SA-6 is adjacent to a retention pond located west of the Saturn Test Stand (Building 4670) in the West Test Area. The pond has been used since 1965 for the retention of liquid wastes from testing activities at the Saturn Test Stand and the F-1 Test Stand (Building 4696). MSFC-004 received liquid wastes from more than 300 firings of the Saturn V rocket. During each test, approximately 2 million gallons of deluge water mixed with RP-1 rocket fuel, combustion products, and TCE were discharged to the pond. After each test, two to four 55-gallon drums of TCE were used to flush the rocket engines and liquid oxygen lines. The TCE flush was also discharged to the pond. The water was retained in the pond until water sampling results indicated that water quality was satisfactory for release to Huntsville Spring Branch.

DA - Department of the Army.

DANC - Decontaminating agent, noncorrosive.

MSFC - George C. Marshall Space Flight Center.

NASA - National Aeronautics and Space Administration.

PCE - Tetrachloroethene.

RP - Rocket propellant.

SA - Source area.

TCE - Trichloroethene.

UST - Underground storage tank.

<sup>a</sup> - Information obtained from the Draft Final Operable Unit 3 Remedial Investigation Report (CH2M Hill, 2012).

<sup>b</sup> - Per ADEM Correspondence dated June 6, 2014, the Army is responsible for surface media and groundwater at this site.  
MSFC-034 is included in Table VI.2 of RSA's Permit (ADEM, 2015).

Table 1-3

**Groundwater Contamination Delineation Responsibility Summary**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

RFI Status	Groundwater Contamination Delineation Responsibility				
		Surface Media Site		RSA-147/148/149 Groundwater Unit	No GW COCs
NFA	14	MSFC-002/087, MSFC-055, MSFC-060, MSFC-065, MSFC-074, MSFC-077, MSFC-D, RSA-102, RSA-103, RSA-104, RSA-105, RSA-106, RSA-107, RSA-119 <sup>a</sup>	11	MSFC-052e <sup>b</sup> , RSA-033, RSA-043, RSA-044, RSA-123, RSA-124, RSA-125, RSA-127, RSA-223, RSA-224, RSA-270	5 RSA-075, RSA-121, RSA-251, RSA-279, RSA-285
Legacy RI, action completed - in LTM	-		5	RSA-049, RSA-053, RSA-054/RSA-055, RSA-060	-
Legacy RI, action required	1	RSA-059	5	RSA-056, RSA-057, RSA-122, RSA-139, RSA-183	-
RFI completed, in review	3	RSA-264, RSA-304, RSA-E	1	RSA-290	2 RSA-216, RSA-F
RFI completed, ADEM concurrence	8	MSFC-027, MSFC-053, RSA-009, RSA-030, RSA-031, RSA-141, RSA-225, RSA-252	4	RSA-226, RSA-227, RSA-240, RSA-277	2 RSA-222, RSA-250
RFI in progress, in field	4	MSFC-003/MSFC-082, MSFC-034, MSFC-035	-		-
RFI in progress, subsequent Rev RFI required	2	RSA-118 <sup>a</sup> , RSA-117	-		-
RFI completed, submittal pending	7	RSA-010, RSA-028, RSA-109, RSA-126, RSA-238, RSA-249, RSA-320	-		-
Deferred	6	RSA-052, RSA-061, RSA-062, RSA-063, RSA-072, RSA-114	-		-
NA or Not under contract	2	RSA-101, RSA-317	-		-

a - Integrated into RSA-117; to be completed as part of parent site RFI (RSA-117)

b - Integrated into RSA-183; to be completed as part of parent site RFI (RSA-183)

Table 2-1

**Chronologic Summary of Dye Tracing  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Injection	Investigator	Location	Dye Injection							Post-Injection Monitoring				Reference
			Injection Point	Zone	Injection Elevation (feet amsl)	Date Injected	Dye	Amount (pounds)	Post-Injection Flush (gal @ rate, gpm)	Locations	Frequency	End Date (Duration)	Dye Detections	
1	GSA	OU-18	MW-051D	BR	500.79	5/7/1992	Fluorescein	1	not reported	Five locations (Matthews Cave, Indian Cr (N), Indian Cr below Martin Rd, NASA (Lagoon) Sp)	5 days	6/1/92 (25d)	Indian Cr below Martin Rd, MW00-901D(?)	Rheams et al, 1994
2	GSA	OU-6 (RSA-10)	RS177	INT	541.1-551.1	4/12/1996	Fluorescein	1	not reported	Six locations (RS086, RS091, RS175, EX01, EX03, RS177)	5 days	5/6/96 (25d)	none (EX01 <sup>1</sup> , EX02 <sup>2</sup> , RS079 <sup>1</sup> , RS080 <sup>2</sup> , RS093 <sup>2</sup> )	GSA, 1996
3			RS178	OVB	558.9-568.9	4/17/1996	Eosine	1	not reported	Six Locations (RS086, RS091, RS175, RS178, EX01, EX03)	5 days	5/6/96 (20d)	none (RS336 <sup>1</sup> )	
4	NASA (CH2M Hill)	NASA-MSFC (OU-18)	IWDY-013	BR	529-534	4/15/1997	Rhodamine WT	0.06	~ 80	MW00-201D (10/2/97-7/28/99), MW00-301D (10/2/97-6/2/99), MW00-401D (8/4/97-6/26/99), MW00-601D (3/11/98-6/2/99), MW00-901D (3/5/98-6/28/99), MW-028D (5/1/97-6/29/99), MW-047D (4/9/97-6/1/99), MWDY-001 (3/6/98-6/1/99), MWDY-002 (3/11/98-6/29/99), MWDY-003 (3/10/98-6/28/99), MWDY-005 (3/18/98-5/29/99), MWDY-006 (12/17/98-6/29/99), MWDY-008 (12/17/98-6/29/99), PZDY-001 (4/10/98-6/29/99), (Grab), MW04-010 (grab), MW00-904 (grab), RS390 (grab), RS392 (grab), RS394 (grab), RS234 (grab), Motherlode Sp (4/15/97-8/19/99), F1 Test Stand (4/14/97-5/14/97), NASA Sp (4/9/97-7/2/99), SV1 Sp, MW00-501D (grab)	graduated <sup>b</sup>		F1 Sp, Isa Sp(?), Midway Sp (?), All Day Sp (?)	CH2M Hill, 2001
5			Site 004	??	??	4/15/1997	Fluorescein	0.70	~ 180		graduated <sup>b</sup>		MW00-201D, RS390, RS392, RS394, RS234,	
6			IWDY-002	BR	562.1-573.1 <sup>c</sup>	4/18/1997	Eosine	7.94	10,000		graduated <sup>b</sup>		MW04-010, MW03-007	
7			IWDY-003	BR	547.8-557.8 <sup>c</sup>	4/18/1997	Sulfurhodamine B	0.60	~ 55		graduated <sup>b</sup>		MW00-601D	
8			IWDY-017	BR	538.4-568.4 <sup>c</sup>	12/8/1997	Fluorescein	0.40	~ 100		graduated <sup>b</sup>		SV1 Sp	
9			Site 004	??	??	12/10/1997	Rhodamine WT	10.00	~ 7,200		graduated <sup>b</sup>		MW00-201D, Motherlode Sp, RS083(?), RS080(?)	
10			MW03-007	OVB	567.6-577.6	3/4/1998	Rhodamine WT	5.00	~ 300		graduated <sup>b</sup>		ABD Sp, Seep Sp, NASA Sp, MW00-301D	
11			MW00-402	OVB	567.9-577.9	3/6/1998	Fluorescein	11.00	~ 200		graduated <sup>b</sup>		MWDY-005, MW00-401D, MW00-601D, MWDY-002(?), MWDY-003(?), MWDY-001(?), RS1099 <sup>a</sup> , RS1129 <sup>a</sup> , RS1055 <sup>a</sup> , RS1136 <sup>a</sup>	
12			MW00-905	INT	558.9-569.9	3/6/1998	Eosine	2.00	300		graduated <sup>b</sup>		MW00-901D, MW00-904	
13			IWDY-001	BR	576.5-586.5 <sup>c</sup>	3/16/1998	Red 28	11.00	300		graduated <sup>b</sup>		NASA Sp, MW-047D, MW-028D(?), RS1099 <sup>a</sup> , RS1129 <sup>a</sup> , RS1130 <sup>a</sup> , RS1133 <sup>a</sup> , RS1135 <sup>a</sup> , RS1136 <sup>a</sup> , RS080 <sup>2</sup> , RS083 <sup>2</sup> , RS389 <sup>2</sup> , RS545 <sup>2</sup>	
14			IWDY-005	BR	536.1-552 <sup>c</sup>	12/14/1998	Fluorescein	5.00	200-300		graduated <sup>b</sup>		MW00-501D, MWDY-008, MWDY-006, MWDY-003(?)	
15			MW00-402	OVB	567.9-577.9	12/14/1998	Eosine	10.00	~ 190		graduated <sup>b</sup>		PZDY-001, RS1055 <sup>a</sup> , RS1056 <sup>a</sup> , RS336 <sup>2</sup>	
16			IWDY-004	BR	507.5-539.9 <sup>c</sup>	12/15/1998	Rhodamine WT	2.00	380		graduated <sup>b</sup>		Isa Sp(?), Midway Sp (?), All Day Sp (?)	
17			IWDY-006	BR	485.6-563.6 <sup>c</sup>	1/4/1999	Sulfurhodamine B	10.00	~ 400		graduated <sup>b</sup>		MW00-601D(?)	

**Table 2-1**  
**Chronologic Summary of Dye Tracing**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Injection	Investigator	Location	Dye Injection						Post-Injection Monitoring				Reference	
			Injection Point	Zone	Injection Elevation (feet amsl)	Date Injected	Dye	Amount (pounds)	Post-Injection Flush (gal @ rate, gpm)	Locations	Frequency	End Date (Duration)		Dye Detections
18	Shaw	Central Redstone Area	Z-RS1237 (INJ-1)	BR	478-575	4/8/2002	D&C Red #28 (AR92)	10.00	12,900	RS1230D, RS1230I, RS1230S, RS1231D, RS1231(a), RS1231(b), RS1231S, RS1232D, RS1232I, RS1232S(a), RS1232S(b), RS1233D, RS1233I, RS1233S, RS1234, RS1235D, RS1235I(a), RS1235I(b), RS1235S, RS1236D, RS1236I, RS1236S(a), RS265, RS054, RS633, RS634, RS1074, RS1076, RS1079, RS1081, RS1083, RS1084, RS1085, RS1087, RS1089, RS1090, RS1091, RS1093, RS1094, RS1095, RS1096, RS1097, RS1098, RS1099, RS1133, RS1134, RS1139, RS1140, RS931, RS933, RS079, RS080, RS081, RS083, RS086, RS087, RS093, RS094, RS095, RS169, RS172, RS175, RS231, RS233, RS235, RS236, RS336, RS389, RS396, RS399, RS407, RS408, RS488, RS489, RS494, RS545, RS546, RS547, RS625, RS626, RS048, RS509, RS510, RS512, RS513, RS514, RS515RS1054, RS521, RS522, RS523, RS524, RS031, RS032, RS033, RS138, RS139, RS179, RS191, RS192, RS193, RS194, RS196, RS270, RS273, RS274, RS275, RS277, RS279, RS280, RS333, RS334, RS335, RS347, RS349, RS350, RS351, RS352, RS353, RS354, RS355, RS356, RS357, RS358, RS359, RS551, RS553, RS562, RS202, RS203, RS300, RS301, RS302, RS305, RS1063, RS1066, RS1068, RS310, RS051, RS519, RS520, RS293, RS020, RS021, RS022, RS023, RS024, RS197, RS198, RS199, RS281, RS282, RS283, RS284, RS285, RS286, RS287, RS288, RS289, RS290, RS291, RS292, RS360, RS361, RS362, RS555, RS556, RS1056, RS1135, RS1136, RS1145, RS734, RS735, RS859, RS739, RS741, RS860, RS861, RS864, RS865, RS1166, RS1188, RS466, RS1050, RS401, RS402, RS461, RS462, RS834, RS835, RS067, RS606, RS805, RS1181, RS968, MW00-201D, MW00-202, MW00-401D, MW00-405, MW00-501D, MW00-601D, MW00-009, MW00-001, MW00-002, MW00-003, MW00-004, MW00-005, MW00-006, MW00-008, MW00-009, PZDY-001, RS893, RS1253, RS1254, RS896, RS897, RS898A, RS1100, RS1102, RS1055, RS1129, RS1130, RS1144, RSP-0694, RSP-0735, RSP-0759, RSP-0760, RSP-0766, RSP-0772, RSP-0780, RSP-0792, RSP-0802, RSP-0824, RSP-0830, RSP-0950, RSP-0992, RSP-1008, RSP-1020, RSP-1026, RSP-1062, RSP-1070, RSP-1076, RSP-1078, RSP-1086, RSP-1088, RSP-1126, RSP-1160, RSP-1174, RSP-1196, RSP-1207, RSP-1212, RSP-1254, RSP-1268, RSP-1269, RSP-1288, RSP-1324, RSP-1326, RSP-1424, RSP-1506, RSP-1512, RSP-1580, RSP-1614, RSP-1638, RSP-1918, RSP-1934, RSP-1948, SW01, SW02, SW03, SW04, SW05, SW06, SW07, SW08, SW09, SW10, SW11, SW12, SW13, SW14, SW15, SW16, SW17, SW18, SW19, SW20, Saturn Test Stand Sump (inside), Saturn Test Stand Sump (outside), SETS-01, SETS-02, SETS-03, SETS-04, SETS-05, SETS-06, SETS-07, SETS-08	graduated <sup>a</sup>	12/23/2002	E-RS1074, E-RS1083, E-RS1095, E-RS1098, E-RS1099, E-RS1139, F10-RS081, F10-RS093, F10-RS094, F10-RS231, F10-RS396, F10-RS489, F10-RS545, F53-RS194, F53-RS196, F53-RS280, F53-RS335, F53-RS359, F60-RS283, F-RS1145, T2-RS1254, RSP-0694 (NASA Sp), RSP-1070, RSP-1086, RSP-1088, RSP-1126, RSP-1160, RSP-1174, RSP-1196, RSP-1212, RSP-1268, RSP-1269, RSP-1288, RSP-1324, RSP-1326, SW14	Shaw, 2004
							Tinopal CBS-x	30.00			graduated <sup>b</sup>	12/24/2002	None	
19			Z-RS1238 (INJ-2)	BR	451-561	4/7/2002	Sulfurhodamine B (AR52)	20.00	2,200		graduated <sup>b</sup>	12/25/2002	Z-RS1230D, Z-RS1230I, E-RS1099, E-RS1140, F104-RS931, F104-RS933, F10-RS233, F122-RS510, F53-RS275, F53-RS358, F60-RS198, F60-RS361, F-RS1145, G12-RS734, G12-RS739, G12-RS741, G113-RS865, MC-MW00-401D, MC-MW00-601D, MC-MWDY-001, RSP-1288, RSP-1918, RSP-1934, RSP-1948, SW01, SW02, SW03, SW08, SW11, SW17, SW20	
20			Z-RS1239 (INJ-3)	BR-D	463-573	4/8/2002	Eosine (AR87)	20.00	16,400		graduated <sup>b</sup>	12/26/2002	Z-RS1233S, E-RS1091, E-RS1094, F10-RS489, G113-RS739, G113-RS741, MC-MW00-405, T82S-RS1102, RSP-1086, RSP-1160, RSP-1196, RSP-1268, RSP-1269, RSP-1326, RSP-1580, RSP-1614, RSP-638, SW05, SW06, SW08, SW10, Saturn Test Stand Sump (outside)	
21			MC-IWDY-002	BR	562.1-573.1	7/17/2002	FD&C Red 3	20.00	19,000		graduated <sup>b</sup>	12/27/2002	E-RS1091, F53-RS194, MC-MW00-405, MC-MW04-009, T82S-RS1102, RSP-0759 (Midway Sp), RSP-0760 (Moore Sp), RSP-0772, RSP-0780, RSP-0792, RSP-0802 (Isa Sp), RSP-1070, RSP-1160, RSP1212	
22			F54-RS203	BR	504.23-519.23	7/16/2002	Fluorescein (AY73)	20.00	6,450		graduated <sup>b</sup>	12/28/2002	Z-RS1233D, Z-RS1233S, F10-RS231, F10-RS389, F10-RS396, F10-RS489, F122-RS509, F53-RS031, F53-RS193, F53-RS194, F53-RS274, F54-RS202, F54-RS203, F60-RS020, F60-RS021, F60-RS199, F60-RS281, F60-RS292, MC-MWDY-006, RSP-0735, RSP-0760 (Moore Sp), RSP-0792, RSP-0802 (Isa Sp), RSP-1008, RSP-1160, RSP-1269, RSP-1324, RSP-1326, RSP-1614, RSP-1638, SW19	

**Table 2-1**

**Chronologic Summary of Dye Tracing  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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<sup>b</sup> Samples (grab water and charcoal packets) collected daily for first 2 weeks, then every 2-3 days during the third week, followed by every 24 days.

<sup>c</sup> Samples collected at daily for 1st week, every 2-days the 2nd week, semi-weekly for weeks 3-4, weekly for weeks 5-8, semi-monthly for weeks 9-12, monthly for 2 months, then at 3-month periods.

<sup>d</sup> Detected during NASA-MSFC study, but no upgradient fluorescein injection.

<sup>e</sup> Detected in IT sampling, 7/00.

<sup>f</sup> Detected in IT sampling of RSA-10 wells, 9/28/00.

amsl - Above mean sea level.

gpm - Gallons per minute.

Table 3-1

**Groundwater Geochemistry**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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GW Unit	Location Code	Screen Midpoint		Sample Zone	Formation	Aquifer	Source	Sample Date	Sample No	pH	SC	Eh	Charge Balance	Water Type	
		Depth	Elevation											Full	Abbreviated
RSA-148	MC-MW00-217	17.0	589.7	OVb	OVb	Shallow	NASA	4/15/2009	KTA009	5.62	0.05	-40	-3.2	Ca-HCO <sub>3</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-327	18.0	565.1	OVb	OVb	Shallow	NASA	8/19/2008	DSI122	6.78	0.27	128	-8.2	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-328	19.0	564.6	OVb	OVb	Shallow	NASA	8/19/2008	DSI123	6.57	0.24	-141	-7.9	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-329	19.0	564.6	OVb	OVb	Shallow	NASA	8/18/2008	DSI124	6.72	0.28	127.7	9.2	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-330	20.5	561.6	OVb	OVb	Shallow	NASA	8/18/2008	DSI126	6.19	0.19	142.5	-3.1	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-331	21.0	560.9	OVb	OVb	Shallow	NASA	8/18/2008	DSI127	6.43	0.25	157.3	-5.9	Ca-Na-HCO <sub>3</sub> -SO <sub>4</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-321	21.5	559.9	OVb	OVb	Shallow	NASA	8/19/2008	DSI121	6.08	0.17	-136	-1.4	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-423	23.0	566.8	OVb	OVb	Shallow	NASA	8/20/2008	DSI134	7.11	0.4	174.6	-4.6	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-425	23.0	566.4	OVb	OVb	Shallow	NASA	8/20/2008	DSI136	6.98	0.41	-147	0.0	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW01-001	23.0	551.5	OVb	OVb	Shallow	NASA	3/24/2004	FOA031	6.96			-3.2	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW01-001	23.0	551.5	OVb	OVb	Shallow	NASA	9/30/2004	FOB031	6.84	0.45		-3.1	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW01-001	23.0	551.5	OVb	OVb	Shallow	NASA	3/24/2005	FPA031	6.87	0.37		-4.7	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW01-001	23.0	551.5	OVb	OVb	Shallow	NASA	9/28/2005	FPB031	6.25	0.39	-45.9	-1.7	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW01-001	23.0	551.5	OVb	OVb	Shallow	NASA	3/23/2006	FQA031	6.83	0.4	-107	11.9	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW01-001	23.0	551.5	OVb	OVb	Shallow	NASA	9/29/2008	FSB031	6.93	0.37	-49	1.8	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW01-001	23.0	551.5	OVb	OVb	Shallow	NASA	4/16/2009	FTA031	6.9	0.42	-134	-3.8	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-429	25.0	566.2	OVb	OVb	Shallow	NASA	8/21/2008	DSI141	6.58	0.35	-124	-10.3	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-422	26.0	563.5	OVb	OVb	Shallow	NASA	8/20/2008	DSI133	6.99	0.34	129.3	-9.1	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-426	26.5	563.4	OVb	OVb	Shallow	NASA	8/20/2008	DSI137	7.11	0.42	125.1	7.7	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-427	28.5	562.3	OVb	OVb	Shallow	NASA	8/21/2008	DSI139	6.84	0.49	-149	2.6	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-304	29.0	577.2	OVb	OVb	Shallow	NASA	3/23/1999	FJA027	6.04	0.24		-5.3	Ca-Mg-Na-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-602	29.0	559.6	OVb	OVb	Shallow	NASA	3/29/2004	FOA010	6.95	0.36		12.4	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-602	29.0	559.6	OVb	OVb	Shallow	NASA	3/24/2005	FPA010	7.11	0.28		8.1	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-602	29.0	559.6	OVb	OVb	Shallow	NASA	9/28/2005	FPB010	6.87	0.29	17.9	-11.3	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-602	29.0	559.6	OVb	OVb	Shallow	NASA	9/26/2007	FRB010	6.49	0.21	28.2	-13.1	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-602	29.0	559.6	OVb	OVb	Shallow	NASA	9/25/2008	FSB010	6.49	0.18	62.5	-1.9	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-602	29.0	559.6	OVb	OVb	Shallow	NASA	4/20/2009	FTA010	6.78	0.21	84	4.8	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-403	33.5	556.3	OVb	OVb	Shallow	NASA	8/20/2008	DSI131	6.95	0.35	-187	0.9	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-148	148-RS2511	34.8	571.2	INT	OVb/Mt-7	Shallow	Army	3/26/2014	AEE3220	5.89	0.42	-57	-13.8	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-404	38.0	560.5	BR	Mt-7	Shallow	NASA	9/19/2006	FQB002	6.69	0.73	53.6	11.1	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-404	38.0	560.5	BR	Mt-7	Shallow	NASA	9/26/2007	FRB002	6.58	0.72	26.9	-14.1	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-404	38.0	560.5	BR	Mt-7	Shallow	NASA	9/25/2008	FSB002	6.47	0.57	-8.1	-13.3	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-404	38.0	560.5	BR	Mt-7	Shallow	NASA	4/20/2009	FTA002	6.76	0.57	21.7	-11.8	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-404	38.0	560.5	BR	Mt-7	Shallow	NASA	9/24/2009	FTB002	6.72	0.69	-62.8	-1.4	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-101Da	39.0	537.2	BR	Mt-7	Shallow	NASA	9/30/2008	DSK005	11.38	1.25	-226	-8.9	Ca-Mg-HCO <sub>3</sub>	Ca-CO <sub>3</sub>
RSA-149	MC-MW00-302Da	39.5	547.6	BR	Mfp-1	Shallow	NASA	3/18/2008	DSB012	8.37	0.56	-306	-3.4	Ca-Mg-Na-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>



Table 3-1

**Groundwater Geochemistry**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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GW Unit	Location Code	Screen Midpoint		Sample Zone	Formation	Aquifer	Source	Sample Date	Sample No	pH	SC	Eh	Charge Balance	Water Type	
		Depth	Elevation											Full	Abbreviated
RSA-148	MC-MW00-507D	40.5	545.7	BR	Mt-5	Shallow	NASA	3/6/2008	DSA004				6.0	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-507D	40.5	545.7	BR	Mt-5	Shallow	NASA	4/22/2009	DTF002	6.86	0.33	98.4	2.6	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-502Da	41.2	538.1	BR	Mt-6/7	Shallow	NASA	12/9/2007	DRV030	7.57	0.4	-202	-5.6	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-502Da	41.2	538.1	BR	Mt-6/7	Shallow	NASA	9/25/2008	DSK056	7.36	0.39	-214	-11.8	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-154	MC-MW00-104Db	48.4	514.0	BR	Mt-5/6	Shallow	NASA	3/14/2008	DSA006	7.39	0.11	-40.7	-6.0	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-154	MC-MW00-104Db	48.4	514.0	BR	Mt-5/6	Shallow	NASA	9/24/2008	DSK029	7.56	0.22	-138	5.1	Ca-Na-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-204Da	48.7	548.9	BR	Mt-6	Shallow	NASA	3/17/2008	DSB043	7.47	0.41	-140	-13.2	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MWBK-007	49.0	594.9	OVb	OVb	Shallow	NASA	3/23/1999	FJA001	7.62	0.29		-2.2	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-102Db	56.9	525.0	BR	Mt-6	Shallow	NASA	12/10/2007	DRV002	9.28	0.63	-336	-13.0	Na-HCO <sub>3</sub> -Cl	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-505D	57.4	526.9	BR-D	Mt-7	Deep	NASA	3/4/2008	DSA002				10.8	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-505D	57.4	526.9	BR-D	Mt-7	Deep	NASA	4/23/2009	DTF001				7.9	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MWBK-012D	66.0	572.1	BR	Mt-8	Shallow	NASA	3/23/1999	FJA040	7.44	0.43		1.9	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-506Da	70.2	509.2	BR	Mt-7/8	Shallow	NASA	3/5/2008	DSA013				1.4	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-302Db	80.5	506.6	BR	Mfp-3	Shallow	NASA	3/18/2008	DSB013	8.69	0.76	-315	-13.2	Na-Cl-HCO <sub>3</sub>	Na-Cl
RSA-149	MC-MW00-302Db	80.5	506.6	BR	Mfp-3	Shallow	NASA	9/29/2008	DSK013	8.5	0.68	-349	10.8	Na-HCO <sub>3</sub> -Cl	Na-HCO <sub>3</sub> -Cl
RSA-154	MC-MW00-104Dc	80.7	481.7	BR	Mt-7	Shallow	NASA	9/24/2008	DSK030	7.68	0.27	-179	-15.0	Na-Ca-Mg-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-901D	90.0	500.6	BR	Mfp-1	Shallow	NASA	3/23/1999	FJA032	7.48	0.37		0.7	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-212Da	91.6	465.7	BR	Mt-7	Shallow	NASA	5/19/2009	DTK001	9.31	0.33	-330	-7.1	Ca-Na-HCO <sub>3</sub> -CO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-204Db	98.7	498.9	BR	Mt-8	Shallow	NASA	9/23/2008	DSK044	7.31	0.33	-192	9.5	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-403Da	105.7	493.0	BR	Mfp-2	Shallow	NASA	9/25/2008	DSK054	7.49	0.44	-286	-3.3	Mg-Ca-HCO <sub>3</sub>	Mg-HCO <sub>3</sub>
RSA-149	MC-MW00-506Db	108.6	470.8	BR	Mfp-1/2	Shallow	NASA	3/5/2008	DSA014				7.8	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-502Db	113.2	466.1	BR	Mfp-2	Shallow	NASA	9/25/2008	DSK057	8.49	0.56	-315	2.1	Na-HCO <sub>3</sub> -Cl	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-506Dc	116.3	463.1	BR	Mfp-2	Shallow	NASA	3/5/2008	DSA015				-8.4	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-506Dc	116.3	463.1	BR	Mfp-2	Shallow	NASA	9/25/2008	DSK063	7.43	0.35	-258	2.1	Mg-Ca-Na-HCO <sub>3</sub>	Mg-HCO <sub>3</sub>
RSA-148	MC-MW00-203Da	127.4	486.2	BR-D	Mfp-1	Deep	NASA	3/12/2008	DSB038	8.16	0.45	-338	-12.9	Na-Mg-Ca-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-203Da	127.4	486.2	BR-D	Mfp-1	Deep	NASA	9/30/2008	DSK038	7.62	0.63	-276	-11.4	Na-Mg-Ca-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-205Dc	128.5	431.8	BR-D	Mfp-3	Deep	NASA	12/9/2007	DRV024	8.18	0.86	-306	-2.6	Na-HCO <sub>3</sub> -Cl-SO <sub>4</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-209D	128.7	471.3	BR	Mt-7	Shallow	NASA	9/18/2007	KRK015	11.24	0.91	-233	-8.8	K-Na-CO <sub>3</sub>	K-CO <sub>3</sub>
RSA-147	147-RS2540S	129.5	452.1	BR-D	Mfp-2	Deep	Army	8/15/2014	AED3235	8.66	0.45	12	14.9	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-506Dd	135.1	444.3	BR-D	Mfp-3	Deep	NASA	3/5/2008	DSA016				-0.2	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-103Da	144.4	426.5	BR-D	Mfp-3	Deep	NASA	9/30/2008	DSK026	8.45	1.36	-366	1.4	Na-HCO <sub>3</sub> -Cl-SO <sub>4</sub>	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-102Dc	146.6	435.3	BR-D	Mfp-3	Deep	NASA	12/10/2007	DRV003	8.56	1.08	-361	5.8	Na-HCO <sub>3</sub> -Cl	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-302Dd	148.0	439.1	BR-D	Mfp-6	Deep	NASA	3/18/2008	DSB016	7.63	5.63	-367	12.3	Na-Cl-HCO <sub>3</sub>	Na-Cl
RSA-149	MC-MW00-302Dd	148.0	439.1	BR-D	Mfp-6	Deep	NASA	9/29/2008	DSK016	7.4	5.8	-393	0.1	Na-Cl-HCO <sub>3</sub>	Na-Cl
RSA-149	MC-MW00-101Dc	152.5	423.7	BR-D	Mfp-4/5	Deep	NASA	9/30/2008	DSK007	8.57	0.92	-286	1.8	Na-SO <sub>4</sub> -HCO <sub>3</sub> -Cl	Na-SO <sub>4</sub>
RSA-148	MC-MW00-212Db	156.7	400.5	BR-D	Mfp-2/3	Deep	NASA	4/20/2009	DTJ002	7.69	0.27	-249	-0.7	Ca-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>

Table 3-1

**Groundwater Geochemistry**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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GW Unit	Location Code	Screen Midpoint		Sample Zone	Formation	Aquifer	Source	Sample Date	Sample No	pH	SC	Eh	Charge Balance	Water Type	
		Depth	Elevation											Full	Abbreviated
RSA-148	MC-MW00-212Db	156.7	400.5	BR-D	Mfp-2/3	Deep	NASA	5/19/2009	DTK002	8.09	0.34	-303	-4.9	Ca-Na-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-602Da	158.6	426.9	BR-D	Mfp-4	Deep	NASA	9/23/2008	DSK066	8.64	0.9	-284	-9.9	Na-HCO <sub>3</sub> -Cl	Na-HCO <sub>3</sub>
RSA-147	147-RS2248S	161.0	418.8	BR-D	Mfp-2	Deep	Army	10/7/2014	AED3238R	12.24	2.99	-213	13.0	Ca-Na-CO <sub>3</sub>	Ca-CO <sub>3</sub>
RSA-154	MC-MW00-104Dd	163.9	398.6	BR-D	Mfp-3	Deep	NASA	3/14/2008	DSA009	7.65	0.18		-8.8	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-503Dc	164.5	398.7	BR-D	Mfp-7	Deep	NASA	9/28/2008	DSK059	8.02	1.33	-349	4.9	Na-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-204Dd	164.9	432.8	BR-D	Mfp-3	Deep	NASA	12/6/2007	DRV019	7.84	0.41	-166	13.2	Na-Mg-Ca-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-205Dd	166.9	393.4	BR-D	Mfp-5	Deep	NASA	12/9/2007	DRV025	7.97	1.48	-332	-9.3	Na-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Na-SO <sub>4</sub>
RSA-148	MC-MW00-205Dd	166.9	393.4	BR-D	Mfp-5	Deep	NASA	3/14/2008	DSB051	8.41	1.41	-276	-14.7	Na-HCO <sub>3</sub> -SO <sub>4</sub>	Na-HCO <sub>3</sub>
RSA-148	148-RS1978c	172.5	411.8	BR-D	Mfp-1/2	Deep	Army	11/20/2014	AEE3217	8.16	5.3	-256	-14.8	Na-SO <sub>4</sub> -HCO <sub>3</sub> -Cl	Na-SO <sub>4</sub>
RSA-148	MC-MW00-203Db	173.6	439.9	BR-D	Mfp-3	Deep	NASA	3/12/2008	DSB039	8.07	1.29	-372	-9.0	Na-Mg-Ca-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-203Db	173.6	439.9	BR-D	Mfp-3	Deep	NASA	9/30/2008	DSK039	7.81	0.76	-279	0.2	Na-Mg-Ca-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-302De	177.3	409.9	BR-D	Mfp-7	Deep	NASA	9/29/2008	DSK017	7.91	5.3	-396	11.5	Na-Cl-HCO <sub>3</sub>	Na-Cl
RSA-148	MC-MW00-205De	179.5	380.9	BR-D	Mfp-5/6	Deep	NASA	3/14/2008	DSB052	7.81	2.86	-283	-12.8	Na-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Na-HCO <sub>3</sub>
RSA-154	MC-MW00-104De	184.1	378.3	BR-D	Mfp-4	Deep	NASA	3/14/2008	DSA010	7.8	0.19	-55.6	-14.1	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-102Dd	188.8	393.1	BR-D	Mfp-5	Deep	NASA	9/29/2008	DSK022	7.64	1.37	-300	-2.7	Na-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-503Dd	193.0	370.2	BR-D	Ord	Deep	NASA	9/28/2008	DSK060	7.96	1.95	-369	5.8	Na-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-602Db	194.1	391.5	BR-D	Mfp-6	Deep	NASA	9/23/2008	DSK068	8.24	1	-304	-9.1	Na-HCO <sub>3</sub> -Cl	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-202Db	199.4	421.7	BR-D	Mfp-4	Deep	NASA	3/11/2008	DSB037	7.69	0.48	-290	7.7	Na-Mg-Ca-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-202Db	199.4	421.7	BR-D	Mfp-4	Deep	NASA	10/1/2008	DSK037	7.59	0.62	-234	0.6	Na-Mg-Ca-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-149	MC-MW00-602Dc	206.5	379.0	BR-D	Mfp-6/7	Deep	NASA	9/23/2008	DSK069	8.26	1.32	-302	-10.4	Na-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-150	150-RS1784c	211.5	361.9	BR-D	Ord	Deep	Army	11/30/2012	ADC3107	7.52	0.6	-197	13.4	Ca-Mg-HCO <sub>3</sub>	Ca-HCO <sub>3</sub>
RSA-149	MC-MW00-403Db	214.0	384.8	BR-D	MDc/Ord	Deep	NASA	9/25/2008	DSK055	7.26	0.95	-282	-0.4	Na-Ca-SO <sub>4</sub> -HCO <sub>3</sub> -Cl	Na-SO <sub>4</sub>
RSA-148	MC-MW00-205Df	224.2	336.2	BR-D	MDc	Deep	NASA	12/9/2007	DRV027	7.39	7.81	-374	3.2	Na-SO <sub>4</sub> -Cl	Na-SO <sub>4</sub>
RSA-148	MC-MW00-205Df	224.2	336.2	BR-D	MDc	Deep	NASA	3/14/2008	DSB053	7.55	4.1	-286	-10.5	Na-SO <sub>4</sub> -HCO <sub>3</sub> -Cl	Na-SO <sub>4</sub>
RSA-149	MC-MW00-506De	231.0	348.4	BR-D	Mfp-7/MDc/Ord	Deep	NASA	3/5/2008	DSA017				-2.7	Ca-Na-Mg-HCO <sub>3</sub> -SO <sub>4</sub> -Cl	Ca-HCO <sub>3</sub>
RSA-148	MC-MW00-212Dd	232.5	324.7	BR-D	Mfp-6	Deep	NASA	5/19/2009	DTK005	9.35	0.43	-27.2	-3.5	Na-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-147	147-RS2540D	245.0	336.6	BR-D	Mfp-7/MDc	Deep	Army	8/19/2014	AED3233	11.74	3.14	-105	5.6	Na-K-CO <sub>3</sub> -SO <sub>4</sub>	Na-CO <sub>3</sub>
RSA-148	MC-MW00-212Df	248.3	308.9	BR-D	Mfp-7	Deep	NASA	4/20/2009	DTJ007	9.25	0.47	-351	-2.6	Na-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-212Df	248.3	308.9	BR-D	Mfp-7	Deep	NASA	5/19/2009	DTK007	9.29	0.44	-362	-3.6	Na-HCO <sub>3</sub>	Na-HCO <sub>3</sub>
RSA-148	MC-MW00-204De	252.8	344.9	BR-D	Ord	Deep	NASA	9/23/2008	DSK047	7.32	1.31	-248	4.3	Na-HCO <sub>3</sub>	Na-HCO <sub>3</sub>

Eh - Oxidation-reduction potential.

SC - Specific conductance.

Groundwater Unit	Boring or Location Code	Screen Depth			Well Type	Total Borehole Depth (ft bgs)	Top Mfp <sup>a</sup> (ft bgs)	Top MDC <sup>b</sup> (ft bgs)	Liner Refusal <sup>c</sup> (ft bgs)	Hydrophysical Testing <sup>f</sup>					Packer Testing <sup>g</sup>					
										Depth (ft bgs)		Ambient Flow Rate <sup>d</sup> (gpm)	Stressed Flow Rate (gpm)	SC (μS/cm)	Depth (ft bgs)	Viable Pumping Rate (gpm)	Drawdown			
RSA-147	Z-RS1230	S	17.0	- 42.0	Nested	144.2	61.7	201.7	not used	49.5	- 50.6	0.01	0.008	782	No packer testing performed					
		I	75.0	- 95.0																
		D	120.0	- 140.0																
RSA-147	Z-RS1235	S	16.0	- 41.9	Nested	156.0	128.4	268.4	not used	34.7	- 35.1	0	0.745	241	No packer testing performed					
		Ia	72.0	- 77.0																
		Ib	92.0	- 102.0																
		D	130.1	- 150.1																
RSA-147	Z-RS1237				Single	148.3	67.5	208.6	not used	58.4	- 58.5	0.017	0.110	362	No packer testing performed					
			70.5	- 80.5																
RSA-147	Z-RS1238		42.0	- 155.0	Open Hole	151.5	68.7	207.3	not used	119.2	- 119.3	0.002	0.018	1480	No packer testing performed					
RSA-147	Z-RS1232	Sa	36.0	- 46.0	Nested	151.0	98.1	238.1	not used						No packer testing performed					
		Sb	61.0	- 71.0																
		I	92.0	- 112.0																
		D	130.0	- 150.0																
RSA-147	Z-RS1232	Sa	36.0	- 46.0	Nested	HpL - Hydrophysical logging.	100.3	243.4	Not Used						No packer testing performed					
		Sb	61.0	- 71.0																
		I	92.0	- 112.0																
		D	130.0	- 150.0																
	147-RS1968		227.0	- 247.0	Single					HpL not run in RS1968. However, RS1968 is paired with RS1232 which was drilled to 155', the HpL results for which are shown (in gray).					154.0	- 157.9	No flow	64.92		
RSA-147	147-RS2248				Nested	308.0	128.7	277.3	277.0	39.2	- 74.0	0.005	0.0078	320						
		S	156.0	- 166.0																

Groundwater Unit	Boring or Location Code	Screen Depth	Well Type	Total Borehole Depth (ft bgs)	Top Mfp <sup>a</sup> (ft bgs)	Top MDc <sup>b</sup> (ft bgs)	Liner Refusal <sup>c</sup> (ft bgs)	Hydrophysical Testing <sup>f</sup>				Packer Testing <sup>g</sup>							
								Depth (ft bgs)	Ambient Flow Rate <sup>d</sup> (gpm)	Stressed Flow Rate (gpm)	SC (μS/cm)	Depth (ft bgs)	Viable Pumping Rate (gpm)	Drawdown					
RSA-147	147-RS2249			Nested	289.0	117.9	264.9	81.0					99.0	- 102.7	0.05	80.51			
		S	133.0						- 143.0										
									111.0	- 113.6	0.004	0.351	644						
									146.6	- 151.9	0	0.01	767	138.0	- 139.7	1.34	62.03		
													166.0	- 171.7	0.57	154.6			
									255.0	- 257.9	0	0.004	930						
				HpL not run in RS2249. However, RS2249 is paired with abandoned RS1167 borehole, the HpL results for which are shown (in gray)				261.0	- 282.0	0.37	124.48								
		D	272.0	- 283.0					279.3	- 283.9	0	0.002	930	272.0	- 282.0	0.98	132.03		
RSA-147	147-RS2250			Nested	311.0	116.1	259.5	Not recorded	No HpL performed				14.4	- 37.5	3.2	4.3			
		S	170.0										- 180.0	153.0	- 156.9	0.0005	49.35		
													171.7	- 175.6	0.97	45.75			
													254.0	- 257.9	No flow	33.09			
													270.0	- 273.9	No flow	31.59			
		D	295.0	- 310.0					290.0	- 307.4	0.0024	62.31							
RSA-147	147-RS1966			Single	287.0	122.0	269.5	Not Used	17.7	- 17.9	0.011	0.72	1224	16.0	- 21.0	1.18	10.37		
									34.0	- 39.0	34.6	- 38.4	0.039	0.48	5460	33.7	- 38.7	0.99	17.99
													50.8	- 55.6	0.09	20.54			
									60.7	- 62.4	0	0.006	5460	56.6	- 60.8	No flow	-		
									87.9	- 92.0	-0.051	0.001	1280	87.4	- 92.4	0.17	92.4		
													175.4	- 180.4	No flow	175			
RSA-147	147-RS2251			Nested	286.0	123.6	268.1	Not recorded	17.7	- 17.9	0.011	0.72	1224	28.0	- 31.9	0.3	29.91		
									34.6	- 38.4	0.039	0.48	5460						
									60.7	- 62.4	0	0.006	5460						
									87.9	- 92.0	-0.051	0.001	1280	87.2	- 91.1	1.46	28.49		
									175.2	- 179.1	0.0007	96.24							
									189.8	- 193.7	No flow	54.11							
									200.6	- 204.5	0.0016	88.01							
		S	86.0	- 96.0					216.8	- 223.4	No flow	60							
						244.6	- 248.6	No flow	81.32										
		D	265.0	- 280.0					262.0	- 286.0	0.0009	61.06							
RSA-147	147-RS2540			Nested	270.0	106.2	250.4	255.0	No HpL performed				270.0	- 46.0	2.5	0.16			
													42.0	- 87.5	1.95	0.09			
													67.8	- 71.8	0.22	23.19			
													87.4	- 91.4	No flow	44.82			
													125.8	- 129.7	0.0016	31.32			
													145.1	- 149.0	0.0008	28.29			
						165.1	- 169.0	No flow	40.09										
						233.8	- 237.9	No flow	43.6										
		D	235.0	- 255.0					245.0	- 270.0	No flow	46.64							
RSA-147	F122-RS513	121.4	- 126.4	Single	127.8	76.3	216.3	not used	No HpL performed				No packer testing performed						

Groundwater Unit	Boring or Location Code		Screen Depth		Well Type	Total Borehole Depth (ft bgs)	Top Mfp <sup>a</sup> (ft bgs)	Top MDc <sup>b</sup> (ft bgs)	Liner Refusal <sup>c</sup> (ft bgs)	Hydrophysical Testing <sup>f</sup>					Packer Testing <sup>g</sup>			
										Depth (ft bgs)		Ambient Flow Rate <sup>d</sup> (gpm)	Stressed Flow Rate (gpm)	SC (μS/cm)	Depth (ft bgs)		Viable Pumping Rate (gpm)	
RSA-148	154-RS1761	S	40.0	- 45.0	Nested	123	NDE	?	not used	No HpL performed					No packer testing performed			
		D	60.0	- 70.0														
RSA-148	154-RS1767		66.0	- 86.0	Single	120	NDE	?	not used	No HpL performed					No packer testing performed			
RSA-148	MC-MW00-104D	a	37.85	- 39.85	FLUTe	258.0	108.5	248.5	Not available	38.8	- 38.9	0	1.331	118	Every 50' while drilling; no results available			
		b	47.4	- 49.4						48.3	- 48.5	0.098	20	88				
		c	79.7	- 81.7						80.6	- 80.8	0	0.113	183				
		d	161.9	- 165.85						163.1	- 164.6	0.013	0.621	183				
		e	182.1	- 186.1						182.9	- 185.3	-0.111	-0.1	NA				
		f	204.1	- 211.05						205.5	- 209.6	0	0.0015	1123				
		g	245.8	- 255.75						247.2	- 254.3	0.0008	0.0011	1123				
RSA-148	MC-MW00-202D	a	185.9	- 189.1	FLUTe	270.0	123.0	263.0	Not available	187.4	- 187.6	0.058	23.2	591	Every 50' while drilling; no results available			
		b	197.8	- 200.9						199.3	- 199.4	0.011	0.031	591				
RSA-148	MC-MW00-203D				FLUTe	266.0	120.0	260.0	Not available	112.6	- 112.7	0.071	29.6	544	Every 50' while drilling; no results available			
		a	125.8	- 128.9						127.3	- 127.4	0	0.008	544				
		b	172.0	- 175.2						173.5	- 173.7	-0.071	0.008	650				
		c	186.7	- 189.8						188.2	- 188.3	0	0.002	650				
		d	237.2	- 240.8						238.7	- 239.3	0.0034	0.001	650				
RSA-148	MC-MW00-204D				FLUTe	255.0	107.0	247.0	Not available	32.7	- 32.8	0.2	0.2	186	Every 50' while drilling; no results available			
		a	47.1	- 50.3						48.6	- 48.8	0	1.65	178				
		b	97.1	- 100.3						98.6	- 98.8	0.003	1.72	385				
		c	156.7	- 159						157.7	- 158.0	-0.203	17.6	519				
		d	163.2	- 166.5						164.7	- 165.0	0.16	1.34	490				
		e	250.5	- 255														
RSA-148	MC-MW00-205D	a	54	- 57.1	FLUTe	233.0	81.0	221.0	Not available	55.5	- 55.6	0	19.8	552	Every 50' while drilling; no results available			
		b	65.2	- 68.3						66.7	- 66.8	0	0.032	1194				
		c	126.9	- 130.1						128.4	- 128.6	0.0007	0.58	1081				
		d	165.3	- 168.5						166.8	- 167.0	0.002	0.2	1389				
		e	177.9	- 181						179.4	- 179.5	0.0009	0.026	1040				
		f	223.5	- 224.8						224.0	- 224.3	0.011	0.125	1989				
RSA-148	MC-MW00-212D	a	89.55	- 93.55	FLUTe	271.0	118.0	258.0	Not available	92.7	- 94.0	0	0.021	690	91.9	- 96.8	NA	NA
		b	154.7	- 158.7						157.6	- 159.4	0.119	14.9	567	156.0	- 160.9	10.51	149.82
		c	218	- 220						220.7	- 220.9	0.124	0.872	721				
		d	231.5	- 233.5						234.2	- 234.4	0.127	1.92	703				
		e	242.2	- 244.15						244.9	- 245.0	0.021	0.348	768				
		f	246.8	- 249.8						249.8	- 250.4	0.024	0.039	768				

Groundwater Unit	Boring or Location Code		Screen Depth		Well Type	Total Borehole Depth (ft bgs)	Top Mfp <sup>a</sup> (ft bgs)	Top MDC <sup>b</sup> (ft bgs)	Liner Refusal <sup>c</sup> (ft bgs)	Hydrophysical Testing <sup>f</sup>				Packer Testing <sup>g</sup>		
										Depth (ft bgs)	Ambient Flow Rate <sup>d</sup> (gpm)	Stressed Flow Rate (gpm)	SC (μS/cm)	Depth (ft bgs)	Viable Pumping Rate (gpm)	Drawdown
RSA-148	F10-RS235		202	- 206	Single	207.0	110.0	250.0	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS236		116	- 125	Single	130.0	92.1	232.1	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS390		135.5	- 145.77	Single	145.8	129.1	269.1	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS399		130.5	- 135.5	Single	136.0	127.6	267.6	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS488		94	- 154	Single	159.0	92.0	232.0	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS489		91	- 151	Single	157.0	91.8	231.8	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS490		118	- 128	Single	133.0	93.1	233.1	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS491		92	- 142	Single	147.0	93.3	233.3	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS492		105	- 165	Single	170.0	108.3	248.3	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS494		93	- 159.5	Open hole	159.5	92.9	232.9	not used	No Hpl. performed				No packer testing performed		
RSA-148	F10-RS545		128	- 138	Single	165.0	125.6	265.6	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS333		150	- 159	Single	160.0	98.7	238.7	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS354		189.5	- 199.5	Single	206.2	87.8	227.8	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS334		132	- 141	Single	146.0	96.7	236.7	not used	No Hpl. performed				No packer testing performed		
RSA-148	F60-RS291		138.7	- 147.7	Single	148.7	90.0	230.0	not used	No Hpl. performed				No packer testing performed		
RSA-148	F60-RS362		155.5	- 165.5	Single	166.0	106.2	246.2	not used	No Hpl. performed				No packer testing performed		
RSA-148	F60-RS561		133	- 143	Single	145.0	79.3	219.3	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS355		144	- 154	Single	156.0	101.7	241.7	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS356		140	- 150	Single	151.0	92.4	232.4	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS357		138	- 147	Single	149.0	92.6	232.6	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS358		120.7	- 130.7	Single	131.2	77.3	217.3	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS562		144	- 154	Single	156.0	119.2	259.2	not used	No Hpl. performed				No packer testing performed		
RSA-148	F53-RS272		59	- 248	Open hole	248.0	96.0	236.0	not used	No Hpl. performed				No packer testing performed		
RSA-148	F54-RS301		139.5	- 143.5	Single	147.0	95.0	235.0	not used	No Hpl. performed				No packer testing performed		
RSA-148	F54-RS302		142	- 146	Single	149.5	98.0	238.0	not used	No Hpl. performed				No packer testing performed		
RSA-148	T-RS1144		156	- 165.75	Single	166.0	52.0	192.0	not used	No Hpl. performed				No packer testing performed		
		a	38.0	- 40.0						38.2	- 38.4	0.026	0.44	1665		
		b	72.5	- 75.0						73.9	- 74.0	0.089	2.33	1115		

Groundwater Unit	Boring or Location Code	Screen Depth			Well Type	Total Borehole Depth (ft bgs)	Top Mfp <sup>a</sup> (ft bgs)	Top MDc <sup>b</sup> (ft bgs)	Liner Refusal <sup>c</sup> (ft bgs)	Hydrophysical Testing <sup>f</sup>					Packer Testing <sup>g</sup>			
										Depth (ft bgs)	Ambient Flow Rate <sup>d</sup> (gpm)	Stressed Flow Rate (gpm)	SC (μS/cm)	Depth (ft bgs)	Viable Pumping Rate (gpm)	Drawdown		
RSA-149	MC-MW00-302D	a	38	- 41	FLUTe	188.0	38.0	178.0	Not available	39.5	- 39.9	4.51	7.54	263	Every 50' while drilling; no results available			
		b	79	- 82														
		c	125	- 128														
		d	146	- 150														
		e	176	- 178.5														
		f	180	- 182														
RSA-149	MC-MW00-403D	a	104.1	- 107.3	FLUTe	218.0	70.0	210.0	Not available	105.6	- 105.8	0.03	0.108	368	Every 50' while drilling; no results available			
		b	212.4	- 215.5						213.9	- 214.0	0.02	0.02	595				
RSA-149	MC-MW00-503D	c	162.8	- 166.1	FLUTe	196.0	39.0	179.0	Not available	122.0	- 122.4	0.003	0.013	1379	Every 50' while drilling; no results available			
		d	190	- 196						164.3	- 164.6	0.024	0.75	1448				
RSA-149	MC-MW00-505D	-	52.4	- 62.4	Single	249.0	94.0	234.0	Not available	No HPL surveys performed due to hole collapse						Every 50' while drilling; no results available		
RSA-149	MC-MW00-506D	a	69.2	- 71.2	FLUTe	239.0	89.5	229.5	Not available	57.3	- 57.8	0.002	NA	237	Every 50' while drilling; no results available			
		b	106.6	- 110.6						70.0	- 70.3	-0.003	NA	242				
		c	114.3	- 118.3						106.4	- 110.7	0.001	0.001	247				
		d	134.1	- 136.1						115.9	- 116.6	0	0.0001	260				
		e	226	- 236						135.0	- 135.2	0	0.00003	263				
										226.0	- 235.9	0.0005	0.004	1018				
RSA-149	MC-MW00-602D	a	156.1	- 161.1	FLUTe	237.0	87.0	227.0	Not available	55.4	- 56.0	0.016	0.106	875	Every 50' while drilling; no results available			
		b	190.6	- 197.6						157.0	- 165.7	0.04	0.93	875				
										191.8	- 193.6	0	0.007	930				
		c	205.5	- 207.5						196.1	- 196.3	0	0.002	930				
										206.4	- 206.6	0	0.001	930				
RSA-149	MC-MWBK-013D		84.0	- 94.0	Single	225.0	75.0	215.0	not used	93.8	- 93.9	NA	NA	NA	Every 50' while drilling; no results available			
					139.8					- 139.9	NA	NA	NA					
					197.7					- 197.8	NA	NA	NA					
					225.2					- 225.3	NA	NA	NA					

Notes:

- <sup>a</sup> - Depth to top of the Fort Payne formation based on gamma-ray log pick, or if Tusculmbia Limestone is absent, depth represents top of bedrock.
- <sup>b</sup> - Depth to top of the Chattanooga Shale, based on gamma-ray log pick.
- <sup>c</sup> - Depth of FLUTe liner refusal. Refusal documents the depth below which there is insufficient permeability to allow the water below the liner to be displaced.
- <sup>d</sup> - Reflects the ambient groundwater flow rate indicated from the hydrophysical testing.
- <sup>e</sup> - Concentrations from groundwater samples collected during packer testing. Italicized values are from definitive groundwater sample collected during the most recent groundwater sample.
- <sup>f</sup> - Deepest flow observed in ambient or stressed hydrophysical testing.
- <sup>g</sup> - Deepest successful (water yielding) packer test result.
- <sup>h</sup> - No flow indicated; well completed to address DNAPL potential

μS/CM - MicroSiemens per centimeter.

AMSL - Above mean sea level.

bgs - Below ground surface.

BoAC - Base of active circulation.

BR - Bedrock.

Table 4-1

**Analytical Sensitivity Evaluation of Undetected Chemicals in Groundwater Samples  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 3)

Chemical	Maximum Analytical Detection Limit (µg/L)	Tap Water PSV <sup>a</sup> (µg/L)	Basis <sup>b</sup> C / N MCL	Maximum Analytical Detection Limit Exceeds PSV?	Number of DLs of Nondetects That Exceed PSV? <sup>c</sup>	Does Current Maximum Detection Limit Exceed PSV?
<b>EXPLOSIVES</b>						
2,4-Dinitrotoluene	0.78	0.11	C <sup>d</sup>	Yes	7 / 35	No
2,6-Dinitrotoluene	0.78	0.11	C <sup>d</sup>	Yes	8 / 40	No
2-Nitrotoluene	0.78	0.31	C	Yes	1 / 36	No
3-Nitrotoluene	0.78	0.17	N	Yes	1 / 39	No
Nitroglycerin	1.96	0.2	N	Yes	1 / 32	No
RDX	0.78	0.7	C	Yes	1 / 37	No
<b>ORGANOCHLORINE PESTICIDES</b>						
Aldrin	0.0066	0.00092	C	Yes	46 / 46	Method Can't Meet PSV
Dieldrin	0.005	0.0018	C	Yes	40 / 45	No
<b>SEMIVOLATILE ORGANICS</b>						
2,4,6-Trichlorophenol	1.25	1.2	N	Yes	4 / 101	No
2,4-Dinitrophenol	12	3.9	N	Yes	74 / 101	No
2,4-Dinitrotoluene	1	0.11	C <sup>d</sup>	Yes	58 / 75	No
2,6-Dinitrotoluene	0.66	0.11	C <sup>d</sup>	Yes	58 / 75	No
3,3'-Dichlorobenzidine	1.25	0.13	C	Yes	39 / 56	No
4,6-Dinitro-2-methylphenol	0.82	0.15	N	Yes	23 / 40	No
4-Chloroaniline	3.2	0.37	C	Yes	53 / 102	No
4-Nitroaniline	5	3.8	C	Yes	24 / 102	No
Benzo(a)anthracene	0.05	0.03	C	Yes	60 / 87	No
Benzo(a)pyrene	0.6	0.2	MCL	Yes	8 / 101	No
Benzo(b)fluoranthene	0.32	0.25	C	Yes	2 / 90	No
Dibenzofuran	1.25	0.79	N	Yes	25 / 102	No
Hexachlorobenzene	1.25	1	MCL	Yes	24 / 102	No
Hexachlorobutadiene	1.25	0.14	C	Yes	85 / 102	No
Hexachloroethane	1.25	0.33	N	Yes	32 / 102	No
Naphthalene	0.45	0.17	C	Yes	7 / 101	No
Nitrobenzene	1.25	0.14	C	Yes	84 / 101	No
N-Nitroso-di-n-propylamine	0.02	0.011	C	Yes	2 / 17	Method Can't Meet PSV
Pentachlorophenol	5	1	MCL	Yes	76 / 101	No
<b>VOLATILE ORGANICS</b>						



Table 4-1

**Analytical Sensitivity Evaluation of Undetected Chemicals in Groundwater Samples**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 2 of 3)

Chemical	Maximum Analytical Detection Limit (µg/L)	Tap Water PSV <sup>a</sup> (µg/L)	Basis <sup>b</sup> C / N MCL	Maximum Analytical Detection Limit Exceeds PSV?	Number of DLs of Nondetects That Exceed PSV? <sup>c</sup>	Does Current Maximum Detection Limit Exceed PSV?
1,1,1-Trichloroethane	250	200	MCL	Yes	2 / 218 e	No
1,1,2,2-Tetrachloroethane	0.5	0.076	C	Yes	152 / 205 e	5 / 29 due to dilution
1,1,2-Trichloroethane	25	5	MCL	Yes	9 / 211 e	No
1,1-Dichloroethane	25	2.8	C	Yes	10 / 212 e	No
1,1-Dichloroethene	25	7	MCL	Yes	8 / 206 e	No
1,2,4-Trichlorobenzene	250	70	MCL	Yes	6 / 161 e	No
1,2-Dichloroethane	25	5	MCL	Yes	9 / 208 e	No
1,2-Dichloropropane	25	5	MCL	Yes	9 / 215 e	No
1,4-Dichlorobenzene	250	75	MCL	Yes	6 / 155 e	No
2-Butanone	2500	560	N	Yes	5 / 215 e	No
2-Hexanone	31.2	3.8	N	Yes	8 / 213 e	No
4-Methyl-2-pentanone	1250	630	N	Yes	2 / 217 e	No
Acetone	2500	1400	N	Yes	2 / 173 e	No
Benzene	25	5	MCL	Yes	5 / 207 e	No
Bromodichloromethane	250	80	MCL	Yes	6 / 217 e	No
Bromoform	250	80	MCL	Yes	6 / 218 e	No
Bromomethane	6.4	0.75	N	Yes	91 / 208 e	5 / 28 due to dilution
Carbon disulfide	250	81	N	Yes	5 / 204 e	No
Carbon tetrachloride	25	5	MCL	Yes	5 / 189 e	No
Chloroform	110	80	MCL	Yes	2 / 135 e	No
Chloromethane	125	19	N	Yes	7 / 214 e	No
cis-1,2-Dichloroethene	250	70	MCL	Yes	6 / 183 e	No
cis-1,3-Dichloropropene	2.5	0.47	C	Yes	11 / 209 e	5 / 28 due to dilution
Dibromochloromethane	250	80	MCL	Yes	6 / 218 e	No
Dichlorodifluoromethane	120	20	N	Yes	7 / 159 e	No
Methyl tert-butyl ether	125	14	C	Yes	6 / 158 e	No
Methylene chloride	10	5	MCL	Yes	1 / 188 e	No
Styrene	250	100	MCL	Yes	5 / 218 e	No
Tetrachloroethene	25	5	MCL	Yes	9 / 196 e	No
trans-1,2-Dichloroethene	250	100	MCL	Yes	5 / 215 e	No
trans-1,3-Dichloropropene	2.5	0.47	C	Yes	11 / 209 e	5 / 28 due to dilution

Table 4-1

**Analytical Sensitivity Evaluation of Undetected Chemicals in Groundwater Samples  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 3 of 3)

Chemical	Maximum Analytical Detection Limit (µg/L)	Tap Water PSV <sup>a</sup> (µg/L)	Basis <sup>b</sup> C / N MCL	Maximum Analytical Detection Limit Exceeds PSV?	Number of DLs of Nondetects That Exceed PSV? <sup>c</sup>	Does Current Maximum Detection Limit Exceed PSV?
Trichloroethene	25	5	MCL	Yes	7 / 103 e	No
Vinyl chloride	18	2	MCL	Yes	9 / 208 e	No

<sup>a</sup> Unless otherwise indicated, the Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:

1) MCL (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).

2) Tapwater regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017, *Regional Screening Levels for Chemical Contaminants at Superfund Sites*, June).

3) In the absence of a published RSL, a structurally similar surrogate may be provided.

<sup>b</sup> Basis of RSL: C - cancer; N - noncancer; MCL - maximum contaminant level.

<sup>c</sup> Sample number statistics represent nondetects only. Detected samples are not included in these statistics.

<sup>d</sup> PSV for dinitrotoluene mixture.

<sup>e</sup> Extremely high concentrations of trichloroethene, chlorobenzene, and carbon tetrachloride resulted in samples analyzed at varying dilution factors of 10, 20, 25, 50, 100, 500, and 1000.

µg/L - Micrograms per liter.

EPA - U.S. Environmental Protection Agency.

Table 4-2

**Statistical Summary of Chemicals in Groundwater, Most Recent Results**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 1 of 7)

Parameter	Samples Analyzed	Detections	BSV	Detections Above BSV	2017 PSV <sup>(1)</sup>	Detections Above PSV	Frequency of Detection <sup>(2)</sup>	Frequency of Exceedance <sup>(3)</sup>
<b>VOLATILES</b>								
Trichloroethene	1029	546	NA	0	5	270	53	26
1,1,2,2-Tetrachloroethane	984	107	NA	0	0.076	107	11	11
Tetrachloroethene	1025	216	NA	0	5	59	21	5.8
Carbon tetrachloride	1028	160	NA	0	5	59	16	5.7
Vinyl chloride	1020	91	NA	0	2	53	8.9	5.2
Chlorobenzene	1032	161	NA	0	100	46	16	4.5
Methylene chloride	991	69	NA	0	5	45	7	4.5
cis-1,2-Dichloroethene	1042	309	NA	0	70	34	30	3.3
Benzene	1032	95	NA	0	5	27	9.2	2.6
Naphthalene	97	2	NA	0	0.17	2	2.1	2.1
Chloroform	1026	419	NA	0	80	20	41	1.9
Freon 113	905	143	NA	0	1000	8	16	0.9
1,1-Dichloroethene	1027	56	NA	0	7	9	5.5	0.9
1,2-Dichloroethane	1027	50	NA	0	5	8	4.9	0.8
1,1,2-Trichloroethane	1025	31	NA	0	5	7	3	0.7
Carbon disulfide	1039	63	NA	0	81	6	6.1	0.6
m-Xylene (1,3-Dimethylbenzene)	173	3	NA	0	19	1	1.7	0.6
1,1-Dichloroethane	1024	37	NA	0	2.8	2	3.6	0.2
Methyl tert-butyl ether	892	11	NA	0	14	2	1.2	0.2
Acetone	1022	110	NA	0	1400	1	11	0.1
1,2-Dichloropropane	1024	15	NA	0	5	1	1.5	0.1
Bromomethane	1003	1	NA	0	0.75	1	0.1	0.1
1,2-Dichloroethene	1	1	NA	0	NA	0	100	0
Toluene	1044	98	NA	0	1000	0	9.4	0
1,4-Dichlorobenzene	839	49	NA	0	75	0	5.8	0
Trichlorofluoromethane	906	49	NA	0	520	0	5.4	0
trans-1,2-Dichloroethene	1041	40	NA	0	100	0	3.8	0
m,p-Xylene	32	1	NA	0	NA	0	3.1	0
1,2-Dichlorobenzene	782	17	NA	0	600	0	2.2	0
Chloromethane	1031	19	NA	0	19	0	1.8	0
Xylene, Total	1191	21	NA	0	10000	0	1.8	0

Table 4-2

**Statistical Summary of Chemicals in Groundwater, Most Recent Results**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Samples Analyzed	Detections	BSV	Detections Above BSV	2017 PSV <sup>(1)</sup>	Detections Above PSV	Frequency of Detection <sup>(2)</sup>	Frequency of Exceedance <sup>(3)</sup>
Bromodichloromethane	1043	14	NA	0	80	0	1.3	0
Ethylbenzene	1044	13	NA	0	700	0	1.2	0
Dichlorodifluoromethane	888	9	NA	0	20	0	1	0
2-Butanone	1041	8	NA	0	560	0	0.8	0
1,3-Dichlorobenzene	823	4	NA	0	NA	0	0.5	0
Chloroethane	1001	4	NA	0	2160	0	0.4	0
1,2,4-Trichlorobenzene	837	2	NA	0	70	0	0.2	0
1,1,1-Trichloroethane	1043	1	NA	0	200	0	0.1	0
4-Methyl-2-pentanone	1044	1	NA	0	630	0	0.1	0
Styrene	1042	1	NA	0	100	0	0.1	0
2-Hexanone	1010	0	NA	0	3.8	0	0	0
Bromochloromethane	18	0	NA	0	8.3	0	0	0
Bromobenzene	1042	0	NA	0	80	0	0	0
trans-1,2-Dichloropropene	1007	0	NA	0	0.47	0	0	0
Dibromochloromethane	1042	0	NA	0	80	0	0	0
trans-1,2-Dichloroethane	2	0	NA	0	63	0	0	0
Chloroacetaldehyde	2	0	NA	0	NA	0	0	0
Hexachlorobutadiene	18	0	NA	0	0.13	0	0	0
Methyl methacrylate	2	0	NA	0	140	0	0	0
trans-1,3-Dichloropropene	1007	0	NA	0	0.47	0	0	0
<b>SEMIVOLATILES</b>								
bis(2-Chloroethyl)ether	154	20	NA	0	0.014	20	13	13
Dibenz(a,h)anthracene	212	31	NA	0	0.025	19	15	9
Benzo(a)anthracene	477	32	NA	0	0.03	25	6.7	5.2
Naphthalene	510	52	NA	0	0.17	25	10	4.9
1-Methylnaphthalene	471	36	NA	0	1.1	13	7.6	2.8
bis(2-Ethylhexyl)phthalate	522	77	NA	0	6	11	15	2.1
Hexachloroethane	544	14	NA	0	0.33	11	2.6	2
Pentachlorophenol	550	6	NA	0	1	6	1.1	1.1
2-Chlorophenol	550	12	NA	0	9.1	5	2.2	0.9
4-Chloroaniline	543	5	NA	0	0.37	4	0.9	0.7
n-Nitroso-di-n-propylamine	144	1	NA	0	0.011	1	0.7	0.7

Table 4-2

**Statistical Summary of Chemicals in Groundwater, Most Recent Results**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Samples Analyzed	Detections	BSV	Detections Above BSV	2017 PSV <sup>(1)</sup>	Detections Above PSV	Frequency of Detection <sup>(2)</sup>	Frequency of Exceedance <sup>(3)</sup>
Dibenzofuran	537	15	NA	0	0.79	3	2.8	0.6
Hexachlorobutadiene	522	6	NA	0	0.14	3	1.1	0.6
2-Methylnaphthalene	561	30	NA	0	3.6	3	5.3	0.5
Benzo(a)pyrene	534	21	NA	0	0.2	2	3.9	0.4
2,6-Dinitrotoluene	260	1	NA	0	0.11	1	0.4	0.4
Benzo(b)fluoranthene	494	32	NA	0	0.25	1	6.5	0.2
Indeno(1,2,3-cd)pyrene	504	26	NA	0	0.25	1	5.2	0.2
Fluorene	537	49	NA	0	29	0	9.1	0
Fluoranthene	535	48	NA	0	80	0	9	0
Phenanthrene	481	42	NA	0	18	0	8.8	0
Pyrene	552	47	NA	0	12	0	8.5	0
Acenaphthene	551	38	NA	0	53	0	8.4	0
Di-n-butyl phthalate	522	35	NA	0	90	0	6.3	0
Anthracene	554	27	NA	0	180	0	4.9	0
Phenol	547	26	NA	0	580	0	4.8	0
Chrysene	561	25	NA	0	28	0	4.5	0
Benzo(k)fluoranthene	556	12	NA	0	1.5	0	4	0
Benzo(ghi)perylene	581	22	NA	0	60	0	3.9	0
Acenaphthylene	561	16	NA	0	47	0	2.9	0
1,4-Dichlorobenzene	55	2	NA	0	75	0	2.3	0
1,2-Dichlorobenzene	184	3	NA	0	803	0	2.1	0
Carbazole	551	11	NA	0	NA	0	2	0
Diethyl phthalate	539	10	NA	0	1500	0	1.9	0
Isophorone	545	5	NA	0	78	0	0.9	0
n-Nitrosodiphenylamine	551	5	NA	0	12	0	0.9	0
Butyl benzyl phthalate	552	3	NA	0	16	0	0.5	0
Dimethyl phthalate	551	3	NA	0	NA	0	0.5	0
Hexachlorobenzene	550	3	NA	0	1	0	0.5	0
2,4-Dichlorophenol	550	2	NA	0	4.6	0	0.4	0
2-Chloronaphthalene	551	2	NA	0	75	0	0.4	0
2-Methylphenol	550	2	NA	0	93	0	0.4	0
Di-n-octyl phthalate	551	2	NA	0	20	0	0.4	0

Table 4-2

**Statistical Summary of Chemicals in Groundwater, Most Recent Results**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Samples Analyzed	Detections	BSV	Detections Above BSV	2017 PSV <sup>(1)</sup>	Detections Above PSV	Frequency of Detection <sup>(2)</sup>	Frequency of Exceedance <sup>(3)</sup>
2,4,5-Trichlorophenol	550	1	NA	0	130	0	0.2	0
2-Nitrophenol	550	1	NA	0	NA	0	0.2	0
3-Methylphenol	553	1	NA	0	750	0	0.2	0
1,2,4-Trichlorobenzene	85	0	NA	0	90	0	0	0
1,3-Dichlorobenzene	102	0	NA	0	NA	0	0	0
2,4-Dichlorophenol	550	0	NA	0	12	0	0	0
2,4-Dimethylphenol	550	0	NA	0	38	0	0	0
1,2-Dinitrophenol	550	0	NA	0	3.9	0	0	0
2,4-Dinitrophenol	550	0	NA	0	0.11	0	0	0
2-Nitroaniline	551	0	NA	0	19	0	0	0
3,3'-Dichlorobenzidine	429	0	NA	0	0.13	0	0	0
5-Methylphenol and 4-Methylphenol	45	0	NA	0	NA	0	0	0
1-Nitroaniline	551	0	NA	0	NA	0	0	0
4-Methyl-2-methylphenol	245	0	NA	0	0.13	0	0	0
4-Chlorophenyl phenyl ether	551	0	NA	0	NA	0	0	0
4-Chloro-3-methylphenol	550	0	NA	0	140	0	0	0
4-Chlorophenyl phenyl ether	551	0	NA	0	NA	0	0	0
4-Nitroaniline	551	0	NA	0	3.8	0	0	0
4-Nitrophenol	550	0	NA	0	NA	0	0	0
Benzoic acid	10	0	NA	0	7500	0	0	0
1,1,1-Trichloro-2,2,2-trifluoroethane	551	0	NA	0	5.9	0	0	0
1,1,2-Chloroisopropylether	551	0	NA	0	71	0	0	0
Hexachlorocyclopentadiene	551	0	NA	0	50	0	0	0
Nitrobenzene	518	0	NA	0	0.14	0	0	0
<b>EXPLOSIVES</b>								
2-Nitrotoluene	304	40	NA	0	0.31	27	13	8.9
Nitrobenzene	283	17	NA	0	0.14	13	6	4.6
1,3-Dinitrobenzene	301	18	NA	0	0.2	11	6	3.7
Nitroglycerin	242	9	NA	0	0.2	9	3.7	3.7
2,6-Dinitrotoluene	247	11	NA	0	0.11	9	4.5	3.6
3-Nitrotoluene	302	13	NA	0	0.17	9	4.3	3
RDX	303	35	NA	0	0.7	7	12	2.3



Table 4-2

**Statistical Summary of Chemicals in Groundwater, Most Recent Results**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Samples Analyzed	Detections	BSV	Detections Above BSV	2017 PSV <sup>(1)</sup>	Detections Above PSV	Frequency of Detection <sup>(2)</sup>	Frequency of Exceedance <sup>(3)</sup>
2,4-Dinitrotoluene	257	7	NA	0	0.11	6	2.7	2.3
2-Amino-4,6-dinitrotoluene	300	35	NA	0	3.9	3	12	1
4-Amino-2,6-dinitrotoluene	301	12	NA	0	3.9	3	4	1
PETN	247	7	NA	0	3.9	1	2.8	0.4
2,4,6-Trinitrotoluene	302	7	NA	0	0.98	1	2.3	0.3
Tetryl	300	6	NA	0	3.9	1	2	0.3
p-Nitrotoluene	301	24	NA	0	4.3	0	8	0
HMX	302	9	NA	0	100	0	3	0
1,3,5-Trinitrobenzene	302	8	NA	0	50	0	2.6	0
<b>PESTICIDES/PCBS</b>								
beta-BHC	438	125	NA	0	0.025	49	29	11
Dieldrin	427	47	NA	0	0.0018	46	11	11
Aldrin	429	38	NA	0	0.00092	38	8.9	8.9
alpha-BHC	438	63	NA	0	0.0072	36	14	8.2
4,4'-DDD	430	68	NA	0	0.032	28	16	6.5
4,4'-DDE	430	78	NA	0	0.046	22	18	5.1
4,4'-DDT	417	91	NA	0	0.23	16	22	3.8
Heptachlor epoxide	430	52	NA	0	0.2	7	12	1.6
Aroclor 1242	267	4	NA	0	0.5	4	1.5	1.5
gamma-BHC (Lindane)	430	76	NA	0	0.2	4	18	0.9
Endrin	430	50	NA	0	2	3	12	0.7
Endrin aldehyde	430	18	NA	0	0.23	3	4.2	0.7
Toxaphene	427	7	NA	0	3	3	1.6	0.7
Aroclor 1016	267	2	NA	0	0.5	2	0.7	0.7
Aroclor 1254	267	1	NA	0	0.5	1	0.4	0.4
gamma-Chlordane	423	83	NA	0	2	1	20	0.2
alpha-Chlordane	431	78	NA	0	2	1	18	0.2
Heptachlor	429	70	NA	0	0.4	1	16	0.2
delta-BHC	430	65	NA	0	0.36	1	15	0.2
Endrin ketone	431	19	NA	0	0.23	1	4.4	0.2
Chlordane, Technical	31	3	NA	0	2	0	9.7	0
Endosulfan I	430	40	NA	0	10	0	9.3	0

Table 4-2

**Statistical Summary of Chemicals in Groundwater, Most Recent Results**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Samples Analyzed	Detections	BSV	Detections Above BSV	2017 PSV <sup>(1)</sup>	Detections Above PSV	Frequency of Detection <sup>(2)</sup>	Frequency of Exceedance <sup>(3)</sup>
Endosulfan II	430	39	NA	0	10	0	9.1	0
Endosulfan sulfate	430	28	NA	0	10	0	6.5	0
Methoxychlor	430	27	NA	0	40	0	6.3	0
Aroclor 1260	267	1	NA	0	0.5	0	0.4	0
Aroclor 1254	267	0	NA	0	0.5	0	0	0
Aroclor 1248	267	0	NA	0	0.5	0	0	0
Aroclor 1242	267	0	NA	0	0.5	0	0	0
Aroclor 1240	267	0	NA	0	0.5	0	0	0
<b>CHEMICAL AGENTS</b>								
Triethylglycol	75	1	NA	0	140	0	1.4	0
1,4-Dithiane	74	0	NA	0	20	0	0	0
1,4-Dithiane	74	0	NA	0	NA	0	0	0
Lewatite	15	0	NA	0	0.009	0	0	0
Mustard Gas	20	0	NA	0	NA	0	0	0
<b>PERCHLORATE</b>								
Perchlorate	239	90	NA	0	15	0	38	0
<b>METALS</b>								
Iron	760	626	12100	32	1400	128	82	4.2
Arsenic	709	149	5.1	70	10	22	21	3.1
Manganese	719	683	3220	16	43	385	95	2.2
Cobalt	677	196	50	7	0.6	126	29	1
Aluminum	677	585	9434	4	2000	30	86	0.6
Mercury	676	58	0.2	22	2	4	8.6	0.6
Nickel	676	302	40	10	100	3	45	0.4
Vanadium	673	133	50	3	8.6	26	20	0.4
Selenium	671	58	5	8	50	3	8.6	0.4
Zinc	664	511	211	17	600	2	77	0.3
Cadmium	669	77	5	2	5	2	12	0.3
Thallium	670	38	5.7	2	2	14	5.7	0.3
Lead	669	180	5.2	28	15	1	27	0.1
Barium	668	690	156	24	2000	0	99	0
Calcium	774	767	144000	30	NA	0	99	0



Table 4-2

**Statistical Summary of Chemicals in Groundwater, Most Recent Results**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Samples Analyzed	Detections	BSV	Detections Above BSV	2017 PSV <sup>(1)</sup>	Detections Above PSV	Frequency of Detection <sup>(2)</sup>	Frequency of Exceedance <sup>(3)</sup>
Sodium	770	750	65600	67	NA	0	97	0
Magnesium	774	693	19413	50	NA	0	90	0
Potassium	768	449	5830	67	NA	0	88	0
Chromium	678	136	16	21	100	0	80	0
Copper	674	111	25	11	1300	0	71	0
Silver	669	81	10	0	9.4	0	6.1	0
Beryllium	680	37	5	0	4	1	5.4	0
Antimony	678	25	17	0	6	1	3.7	0

**Bold** Frequency of exceedance is greater than 0 percent.

Frequency of exceedance is 0 percent.

BSV - Background screening value (micrograms per liter).

PSV - Preliminary screening value (micrograms per liter).

<sup>(1)</sup> Unless otherwise indicated, the Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:

1) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).

2) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017, *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, June, <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017>). The health advisory level is used for perchlorate (DoD, 2009, *Perchlorate Release Management Policy*, Memorandum from Wayne Army to Deputy Assistant Secretaries of the Army, Navy, and Air Force, 4 April).

<sup>(2)</sup> Ratio of detected concentrations in usable samples to the total number of samples collected.

<sup>(3)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of usable samples analyzed.

Table 4-3

**Statistical Summary of Chemicals in Surface Water, Most Recent Data**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Filtered	Samples Analyzed	Detections	Frequency of Detection	Frequency of Exceedance <sup>(1)</sup>	BSV	Detections Above BSV	2014 PSV <sup>(2)</sup>	Detections Above PSV
<b>VOLATILES</b>									
Trichloroethene	N	81	51	63%	51%	NA	0	2.4	41
1,1,2,2-Tetrachloroethane	N	81	33	41%	41%	NA	0	0.163	33
Carbon tetrachloride	N	81	26	32%	28%	NA	0	0.21	23
Tetrachloroethene	N	81	41	51%	25%	NA	0	0.603	20
Vinyl chloride	N	81	5	6.2%	6.2%	NA	0	0.0246	5
Chloroform	N	73	46	63%	4.1%	NA	0	5.43	3
1,2-Dichloroethane	N	81	3	3.7%	3.7%	NA	0	0.378	3
cis-1,2-Dichloroethene	N	81	42	52%	0%	NA	0	70	0
Acetone	N	77	15	19%	0%	NA	0	1400	0
Methyl Acetate	N	8	1	13%	0%	NA	0	2000	0
Freon 113	N	54	6	11%	0%	NA	0	5500	0
Toluene	N	81	7	8.6%	0%	NA	0	1206	0
Ethylbenzene	N	81	4	4.9%	0%	NA	0	448	0
Xylene, Total	N	81	4	4.9%	0%	NA	0	10000	0
1,1,2-Trichloroethane	N	81	2	2.5%	0%	NA	0	0.575	0
1,1-Dichloroethene	N	81	2	2.5%	0%	NA	0	323	0
Trichlorofluoromethane	N	54	1	2%	0%	NA	0	110	0
2-Butanone	N	81	1	1%	0%	NA	0	560	0
Chloroethane	N	81	1	1%	0%	NA	0	2100	0
1,1,1-Trichloroethane	N	81	0	0%	0%	NA	0	200	0
1,1-Dichloroethane	N	81	0	0%	0%	NA	0	2.7	0
1,2,4-Trichlorobenzene	N	50	0	0%	0%	NA	0	25.8	0
1,2-Dibromo-3-chloropropane	N	8	0	0%	0%	NA	0	0.2	0
1,2-Dibromoethane	N	8	0	0%	0%	NA	0	0.05	0
1,2-Dichlorobenzene	N	50	0	0%	0%	NA	0	344	0
1,2-Dichloropropane	N	81	0	0%	0%	NA	0	0.492	0
1,3-Dichlorobenzene	N	50	0	0%	0%	NA	0	256	0
1,4-Dichlorobenzene	N	50	0	0%	0%	NA	0	51.1	0
2-Hexanone	N	81	0	0%	0%	NA	0	3.8	0
4-Methyl-2-pentanone	N	81	0	0%	0%	NA	0	120	0
Benzene	N	81	0	0%	0%	NA	0	1.12	0
Bromodichloromethane	N	81	0	0%	0%	NA	0	0.534	0

Table 4-3

**Statistical Summary of Chemicals in Surface Water, Most Recent Data**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Filtered	Samples Analyzed	Detections	Frequency of Detection	Frequency of Exceedance <sup>(1)</sup>	BSV	Detections Above BSV	2014 PSV <sup>(2)</sup>	Detections Above PSV
Bromoform	N	81	0	0%	0%	NA	0	4.19	0
Bromomethane	N	77	0	0%	0%	NA	0	46.4	0
Carbon disulfide	N	81	0	0%	0%	NA	0	81	0
Chlorobenzene	N	81	0	0%	0%	NA	0	121	0
Chloromethane	N	81	0	0%	0%	NA	0	19	0
cis-1,3-Dichloropropene	N	81	0	0%	0%	NA	0	0.47	0
Cyclohexane	N	8	0	0%	0%	NA	0	1300	0
Dibromochloromethane	N	81	0	0%	0%	NA	0	0.3945	0
Dichlorodifluoromethane	N	54	0	0%	0%	NA	0	20	0
Isopropylbenzene	N	8	0	0%	0%	NA	0	45	0
Methyl tert-butyl ether	N	54	0	0%	0%	NA	0	14	0
Methylcyclohexane	N	8	0	0%	0%	NA	0	NA	0
Methylene chloride	N	79	0	0%	0%	NA	0	4.6	0
m-Xylene	N	3	0	0%	0%	NA	0	19	0
o-Xylene	N	3	0	0%	0%	NA	0	19	0
Styrene	N	81	0	0%	0%	NA	0	100	0
trans-1,2-Dichloroethene	N	81	0	0%	0%	NA	0	137	0
trans-1,3-Dichloropropene	N	81	0	0%	0%	NA	0	0.47	0
<b>SEMIVOLATILES</b>									
Benzenecarbonal	N	5	1	20%	0%	NA	0	190	0
Phenol	N	26	1	4%	0%	NA	0	10284	0
1,2,4-Trichlorobenzene	N	4	0	0%	0%	NA	0	25.8	0
1,2-Dichlorobenzene	N	4	0	0%	0%	NA	0	344	0
1,3-Dichlorobenzene	N	4	0	0%	0%	NA	0	256	0
1,4-Dichlorobenzene	N	4	0	0%	0%	NA	0	51.1	0
1-Methylnaphthalene	N	22	0	0%	0%	NA	0	1.1	0
2,4,5-Trichlorophenol	N	26	0	0%	0%	NA	0	1800	0
2,4,6-Trichlorophenol	N	26	0	0%	0%	NA	0	0.979	0
2,4-Dichlorophenol	N	26	0	0%	0%	NA	0	65.2	0
2,4-Dimethylphenol	N	26	0	0%	0%	NA	0	291	0
2,4-Dinitrophenol	N	26	0	0%	0%	NA	0	68.5	0
2,4-Dinitrotoluene	N	26	0	0%	0%	NA	0	0.107	0
2,6-Dinitrotoluene	N	26	0	0%	0%	NA	0	0.11	0

Table 4-3

**Statistical Summary of Chemicals in Surface Water, Most Recent Data**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Filtered	Samples Analyzed	Detections	Frequency of Detection	Frequency of Exceedance <sup>(1)</sup>	BSV	Detections Above BSV	2014 PSV <sup>(2)</sup>	Detections Above PSV
2-Chloronaphthalene	N	26	0	0%	0%	NA	0	695	0
2-Chlorophenol	N	26	0	0%	0%	NA	0	58.1	0
2-Methylnaphthalene	N	26	0	0%	0%	NA	0	3.6	0
2-Methylphenol	N	26	0	0%	0%	NA	0	93	0
2-Nitroaniline	N	26	0	0%	0%	NA	0	19	0
2-Nitrophenol	N	26	0	0%	0%	NA	0	NA	0
3,3'-Dichlorobenzidine	N	26	0	0%	0%	NA	0	0.0137	0
3-Nitroaniline	N	26	0	0%	0%	NA	0	NA	0
4,6-Dinitro-2-methylphenol	N	26	0	0%	0%	NA	0	12.6	0
4-Bromophenyl phenyl ether	N	26	0	0%	0%	NA	0	NA	0
4-Chloro-3-methylphenol	N	26	0	0%	0%	NA	0	140	0
4-Chloroaniline	N	26	0	0%	0%	NA	0	0.36	0
4-Chlorophenyl phenyl ether	N	26	0	0%	0%	NA	0	NA	0
4-Methylphenol	N	26	0	0%	0%	NA	0	190	0
4-Nitroaniline	N	26	0	0%	0%	NA	0	3.8	0
4-Nitrophenol	N	26	0	0%	0%	NA	0	NA	0
Acenaphthene	N	26	0	0%	0%	NA	0	454	0
Acenaphthylene	N	26	0	0%	0%	NA	0	52	0
Acetophenone	N	5	0	0%	0%	NA	0	190	0
Anthracene	N	26	0	0%	0%	NA	0	7241	0
Benzo(a)anthracene	N	26	0	0%	0%	NA	0	0.0033	0
Benzo(a)pyrene	N	26	0	0%	0%	NA	0	0.0033	0
Benzo(b)fluoranthene	N	26	0	0%	0%	NA	0	0.0033	0
Benzo(ghi)perylene	N	26	0	0%	0%	NA	0	60	0
Benzo(k)fluoranthene	N	26	0	0%	0%	NA	0	0.0033	0
Bibenzene	N	5	0	0%	0%	NA	0	0.083	0
bis(2-Chloroethoxy)methane	N	26	0	0%	0%	NA	0	5.9	0
bis(2-Chloroethyl)ether	N	26	0	0%	0%	NA	0	0.0288	0
bis(2-Chloroisopropyl)ether	N	26	0	0%	0%	NA	0	1350	0
bis(2-Ethylhexyl)phthalate	N	23	0	0%	0%	NA	0	0.847	0
Butyl benzyl phthalate	N	26	0	0%	0%	NA	0	971	0
Caprolactam	N	5	0	0%	0%	NA	0	990	0
Carbazole	N	26	0	0%	0%	NA	0	NA	0

Table 4-3

**Statistical Summary of Chemicals in Surface Water, Most Recent Data**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Filtered	Samples Analyzed	Detections	Frequency of Detection	Frequency of Exceedance <sup>(1)</sup>	BSV	Detections Above BSV	2014 PSV <sup>(2)</sup>	Detections Above PSV
Chrysene	N	26	0	0%	0%	NA	0	0.0033	0
Dibenz(a,h)anthracene	N	26	0	0%	0%	NA	0	0.0033	0
Dibenzofuran	N	26	0	0%	0%	NA	0	0.79	0
Diethyl phthalate	N	26	0	0%	0%	NA	0	13365	0
Dimethyl phthalate	N	26	0	0%	0%	NA	0	227273	0
Di-n-butyl phthalate	N	26	0	0%	0%	NA	0	1499	0
Di-n-octyl phthalate	N	26	0	0%	0%	NA	0	20	0
Fluoranthene	N	26	0	0%	0%	NA	0	76.7	0
Fluorene	N	26	0	0%	0%	NA	0	966	0
Hexachlorobenzene	N	26	0	0%	0%	NA	0	0.0002	0
Hexachlorobutadiene	N	26	0	0%	0%	NA	0	0.431	0
Hexachlorocyclopentadiene	N	26	0	0%	0%	NA	0	39.4	0
Hexachloroethane	N	26	0	0%	0%	NA	0	1.09	0
Indeno(1,2,3-cd)pyrene	N	26	0	0%	0%	NA	0	0.0033	0
Isophorone	N	26	0	0%	0%	NA	0	34.6	0
Naphthalene	N	26	0	0%	0%	NA	0	0.17	0
Nitrobenzene	N	26	0	0%	0%	NA	0	16.8	0
n-Nitroso-di-n-propylamine	N	26	0	0%	0%	NA	0	0.0049	0
n-Nitrosodiphenylamine	N	26	0	0%	0%	NA	0	2.35	0
Pentachlorophenol	N	26	0	0%	0%	NA	0	0.25	0
Phenanthrene	N	26	0	0%	0%	NA	0	18	0
Pyrene	N	25	0	0%	0%	NA	0	724	0
<b>EXPLOSIVES</b>									
Nitroglycerin	N	42	2	4.8%	4.8%	NA	0	0.2	2
2-Nitrotoluene	N	69	2	2.9%	2.9%	NA	0	0.31	2
2-Amino-4,6-dinitrotoluene	N	69	4	5.8%	0%	NA	0	3.9	0
Nitrobenzene	N	69	3	4.3%	0%	NA	0	16.8	0
RDX	N	69	3	4.3%	0%	NA	0	0.7	0
Tetryl	N	69	3	4%	0%	NA	0	3.9	0
HMX	N	69	2	3%	0%	NA	0	100	0
1,3,5-Trinitrobenzene	N	69	0	0%	0%	NA	0	59	0
1,3-Dinitrobenzene	N	69	0	0%	0%	NA	0	0.2	0
2,4,6-Trinitrotoluene	N	69	0	0%	0%	NA	0	0.98	0

Table 4-3

**Statistical Summary of Chemicals in Surface Water, Most Recent Data**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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Parameter	Filtered	Samples Analyzed	Detections	Frequency of Detection	Frequency of Exceedance <sup>(1)</sup>	BSV	Detections Above BSV	2014 PSV <sup>(2)</sup>	Detections Above PSV
2,4-Dinitrotoluene	N	69	0	0%	0%	NA	0	0.107	0
2,6-Dinitrotoluene	N	69	0	0%	0%	NA	0	0.11	0
3-Nitrotoluene	N	69	0	0%	0%	NA	0	0.17	0
4-Amino-2,6-dinitrotoluene	N	69	0	0%	0%	NA	0	3.9	0
PETN	N	42	0	0%	0%	NA	0	3.9	0
p-Nitrotoluene	N	69	0	0%	0%	NA	0	4.2	0
<b>PESTICIDES/PCBS</b>									
beta-BHC	N	64	20	31%	28%	NA	0	0.0066	18
4,4'-DDD	N	63	15	24%	24%	NA	0	0.0002	15
4,4'-DDE	N	64	14	22%	22%	NA	0	0.0001	14
4,4'-DDT	N	53	3	5.7%	5.7%	NA	0	0.0001	3
Dieldrin	N	64	4	6.3%	6.3%	NA	0	0.00003	4
alpha-BHC	N	64	3	4.7%	4.7%	NA	0	0.0019	3
Heptachlor	N	64	3	4.7%	4.7%	NA	0	0.00005	3
Heptachlor epoxide	N	64	3	4.7%	4.7%	NA	0	0.00002	3
delta-BHC	N	64	4	6.3%	3.1%	NA	0	0.0123	2
alpha-Chlordane	N	64	9	14%	0%	NA	0	2	0
gamma-Chlordane	N	64	7	11%	0%	NA	0	2	0
gamma-BHC (Lindane)	N	64	4	6.3%	0%	NA	0	0.712	0
Endosulfan sulfate	N	64	2	3.1%	0%	NA	0	41.6	0
Endrin	N	64	2	3.1%	0%	NA	0	0.035	0
Methoxychlor	N	64	2	3.1%	0%	NA	0	100	0
Endosulfan I	N	64	1	1.6%	0%	NA	0	41.6	0
Endrin aldehyde	N	64	1	1.6%	0%	NA	0	0.173	0
Endrin ketone	N	64	1	1.6%	0%	NA	0	0.23	0
Aldrin	N	64	0	0%	0%	NA	0	0.00003	0
Aroclor 1016	N	33	0	0%	0%	NA	0	0.00004	0
Aroclor 1221	N	33	0	0%	0%	NA	0	0.00004	0
Aroclor 1232	N	33	0	0%	0%	NA	0	0.00004	0
Aroclor 1242	N	33	0	0%	0%	NA	0	0.00004	0
Aroclor 1248	N	33	0	0%	0%	NA	0	0.00004	0
Aroclor 1254	N	33	0	0%	0%	NA	0	0.00004	0
Aroclor 1260	N	33	0	0%	0%	NA	0	0.00004	0

Table 4-3

**Statistical Summary of Chemicals in Surface Water, Most Recent Data  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Parameter	Filtered	Samples Analyzed	Detections	Frequency of Detection	Frequency of Exceedance <sup>(1)</sup>	BSV	Detections Above BSV	2014 PSV <sup>(2)</sup>	Detections Above PSV
Chlordane, Technical	N	5	0	0%	0%	NA	0	0.0005	0
Endosulfan II	N	64	0	0%	0%	NA	0	41.6	0
Toxaphene	N	64	0	0%	0%	NA	0	0.0002	0
<b>OP PESTICIDES</b>									
Atrazine	N	5	0	0%	0%	NA	0	3	0
<b>CHEMICAL AGENT BREAKDOWN PRODUCTS</b>									
1,4-Dithiane	N	4	0	0%	0%	NA	0	20	0
1,4-Oxathiane	N	4	0	0%	0%	NA	0	NA	0
Thiodiglycol	N	4	0	0%	0%	NA	0	140	0
<b>PERCHLORATE</b>									
Perchlorate	Y	55	39	71%	0%	NA	0	15	0
Perchlorate	N	9	3	33%	0%	NA	0	15	0
<b>METALS</b>									
Arsenic	Y	57	5	9%	9%	4.4	5	0.1205	5
Arsenic	N	69	6	9%	7%	4.4	5	0.1205	6
Iron	N	69	66	96%	4.3%	9860	3	300	41
Aluminum	N	69	67	97%	2.9%	4760	2	2000	6
Lead	N	69	16	23%	2.9%	5.4	4	15	2
Cobalt	N	69	7	10%	2.9%	5.4	2	0.6	4
Vanadium	N	69	7	10%	2.9%	9.7	2	8.6	2
Thallium	N	69	3	4%	2.9%	3	2	0.174	3
Iron	Y	57	35	61%	1.8%	9860	1	300	6
Manganese	N	69	67	97%	1.4%	4894	1	50	46
Chromium	N	69	19	28%	1.4%	8.5	4	100	1
Barium	Y	57	57	100%	0%	181.95	0	1000	0
Barium	N	69	69	100%	0%	181.95	1	1000	0
Calcium	Y	57	57	100%	0%	93900	0	NA	0
Calcium	N	69	69	100%	0%	93900	0	NA	0
Sodium	Y	57	57	100%	0%	7440	10	NA	0
Sodium	N	69	69	100%	0%	7440	12	NA	0
Magnesium	N	69	68	99%	0%	7920	1	NA	0
Magnesium	Y	57	55	96%	0%	7920	2	NA	0
Manganese	Y	57	50	88%	0%	4894	0	50	31



Table 4-3

**Statistical Summary of Chemicals in Surface Water, Most Recent Data  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Parameter	Filtered	Samples Analyzed	Detections	Frequency of Detection	Frequency of Exceedance <sup>(1)</sup>	BSV	Detections Above BSV	2014 PSV <sup>(2)</sup>	Detections Above PSV
Aluminum	Y	57	38	67%	0%	4760	0	2000	0
Zinc	N	69	30	43%	0%	26	3	6158	0
Zinc	Y	57	16	28%	0%	26	3	6158	0
Potassium	N	69	17	25%	0%	4650	1	NA	0
Potassium	Y	57	10	18%	0%	4650	0	NA	0
Copper	N	69	8	12%	0%	5	3	1300	0
Nickel	N	69	8	12%	0%	5.6	3	411	0
Cadmium	N	69	7	10%	0%	1	5	5	0
Copper	Y	57	3	5.3%	0%	5	0	1300	0
Silver	N	69	3	4.3%	0%	1	3	9.4	0
Chromium	Y	57	2	3.5%	0%	8.5	0	100	0
Lead	Y	57	2	3.5%	0%	5.4	0	15	0
Cobalt	Y	57	1	1.8%	0%	5.4	0	0.6	0
Nickel	Y	57	1	1.8%	0%	5.6	0	411	0
Thallium	Y	57	1	1.8%	0%	3	0	0.174	1
Vanadium	Y	57	1	1.8%	0%	9.7	0	8.6	0
Antimony	N	69	1	1.4%	0%	10	0	5.5	0
Mercury	N	69	1	1.4%	0%	0.08	0	0.042	0
Selenium	N	69	1	1.4%	0%	3	0	163	0
Antimony	Y	57	0	0%	0%	10	0	5.5	0
Beryllium	Y	57	0	0%	0%	1	0	4	0
Beryllium	N	69	0	0%	0%	1	0	4	0
Cadmium	Y	57	0	0%	0%	1	0	5	0
Mercury	Y	57	0	0%	0%	0.08	0	0.042	0
Selenium	Y	57	0	0%	0%	3	0	163	0
Silver	Y	57	0	0%	0%	1	0	9.4	0



**Table 4-3**

**Statistical Summary of Chemicals in Surface Water, Most Recent Data  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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<sup>(1)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of samples analyzed.

**Bold** Frequency of exceedance is greater than 0 percent.

Frequency of exceedance is 0 percent.

BSV - Background screening value (micrograms per liter).

PSV - Preliminary screening value (micrograms per liter).

<sup>(2)</sup> The Redstone-specific preliminary screening levels (PSV) for surface water are determined by the following hierarchy:

1) Alabama water quality criteria (WQC) based on human health water quality criteria for consumption of water and fish. Value

2) National WQC based on water quality criteria for human health consumption of water and organisms (EPA, 2012, *National Recommended Water Quality Criteria: 2012*, Office of Water, Office of Science and Technology, on line).

3) Groundwater/tap water PSVs determined by the following hierarchy:

a) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).

b) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2014, *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, May [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration\\_table/index.htm](http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm)).

Table 5-1

**Locations That Exceed Solubility Criteria, Indicating the Potential for DNAPL,  
Most Recent Sample Results  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

Associated Army SWMU or NASA/MSFC Site	Location	Sampled Zone	Hydrologic Zone	Visual Observation <sup>a</sup>	TCE	Carbon Tetrachloride	Chlorobenzene
MSFC-034	MC-MW00-404	OVb	SHALLOW			> 10% S	
	MC-MW00-420	OVb	SHALLOW				
RSA-053	F53-RS359	BR	SHALLOW				
							> 10% S
RSA-117	117-RS2332	OVb	SHALLOW				
	117-RS2333	OVb	SHALLOW				> 10% S
	117-RS2456	OVb	SHALLOW				> 10% S
	147-RS2540D	BR-D	DEEP	Positive			> 10% S
	147-RS1966	BR	SHALLOW	Positive			> 1% S
	147-RS2250D	BR-D	DEEP	Positive			
	147-RS2250S	BR-D	DEEP				> 10% S
	147-RS2251D	BR-D	DEEP	Positive			> 10% S
	147-RS2251S	BR	SHALLOW				> 10% S
	Z-RS1232D	BR-D	DEEP				> 10% S
RSA-141	MC-MW00-505	OVb	SHALLOW				
	T141-RS893	OVb	SHALLOW				
	T141-RS894	OVb	SHALLOW				
	T141-RS895	OVb	SHALLOW				
RSA-183							

<sup>a</sup> - Includes visual observation of product in borehole or staining of reactive ribbon liner at the time of drilling.

> 1% S
> 10% S

Groundwater sample concentration exceeds **1 percent** of the contaminant's solubility value (see below)  
Groundwater sample concentration exceeds **10 percent** of the contaminant's solubility value (see below)  
Indicates location for which the RSA-147/148/149 groundwater units are responsible

	Solubility (S) Threshold Concentrations		
	S (mg/L)	10% S (µg/L)	1% S (µg/L)
TCE	1,100	110,000	11,000
Carbon Tetrachloride	793	79,300	7,930
Chlorobenzene	498	49,800	4,980

µg/L - Micrograms per liter.

DNAPL - Dense nonaqueous-phase liquid.

mg/L - Milligrams per liter.

TCE - Trichloroethene.

[illegible]

Monitored Zone	Location	Sample Number	Sample Date	Units	Arsenic	VQ	Cadmium	VQ	Chromium	VQ	Iron	VQ	Lead	V
Shallow Flow Zone	F53-RS138	AEE3094	29-Nov-12	µg/L							44000			
	F53-RS139	AEE3095	9-Nov-12	µg/L							50000			
	F53-RS140	AEE3100	4-Dec-12	µg/L										
	F54-RS036	FM3047	13-Feb-12	µg/L							13800			
	F54-RS036A	FM3049	16-Feb-12	µg/L										
	F54-RS303	FM3061	16-Feb-12	µg/L							49100			
	F54-RS304	AEE3116	13-Nov-12	µg/L	30									
	F55-RS308	FM3071	8-Feb-12	µg/L										
	F55-RS309	AEE3117	8-Feb-12	µg/L	1000									
	F60-RS021	AED3120	6-Nov-12	µg/L	32						15000			
	F60-RS198	AEE3125	15-Nov-12	µg/L			67							
	F60-RS284	AEE3127	19-Nov-12	µg/L	20						34000			
	F60-RS292	AEE3133	16-Nov-12	µg/L							13000			
Spring (Groundwater)	FE-RS1444	AFQ3009	18-Jun-13	µg/L							68100			
	MC-MW00-425	DSI136	20-Aug-08	µg/L										
Surface Water	RSP-1290	Z2952	17-Mar-09	µg/L							20400	J		
	RSP-1326	AEE3258	5-Mar-14	µg/L							17300			
	RSP-0373	ADC2024	10-Feb-12	µg/L					115					
	RSP-1504	AED2005	22-May-13	µg/L	10.6									
	RSP-1506a	Z2920	19-Mar-09	µg/L	11.2									
	RSP-1506ax	Z2921	19-Mar-09	µg/L	14.2									
Deep Flow Zone	RSP-1510a	AED2010	21-May-13	µg/L	6.26	J								
	F10-RS489	Q30372	4-Feb-09	µg/L									15.5	

VQ - Validation qualifier.

µg/L - Micrograms per liter.

J - The analyte was positively identified, but the reported value is an estimated concentration.

Indicates a location for which delineation is the responsibility of the RSA-147/148/149 groundwater units.

Table 5-3

**Contaminants Exceeding Screening Criteria by Focus Area**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

FocusArea	VOCs	SVOCs	Pesticides	Explosives	Metals
1	Trichloroethene				
2	1,1,2,2-Tetrachloroethane Bromomethane Tetrachloroethene Trichloroethene	Benzo(a)anthracene Benzo(a)pyrene bis(2-Ethylhexyl)phthalate Dibenz(a,h)anthracene Naphthalene			Arsenic Manganese
3	1,1,2,2-Tetrachloroethane Carbon tetrachloride Trichloroethene				
4	1,1,2,2-Tetrachloroethane 1,1-Dichloroethane Acetone Benzene Chlorobenzene Chloroform Methylene chloride Trichloroethene Vinyl chloride		4,4'-DDD 4,4'-DDE alpha-BHC beta-BHC Aldrin Dieldrin	1,3-Dinitrobenzene 2,4,6-Trinitrotoluene 2,4-Dinitrotoluene 2-Amino-4,6-dinitrotoluene 2-Nitrotoluene 3-Nitrotoluene 4-Amino-2,6-dinitrotoluene Nitroglycerin PETN RDX	Manganese
5	1,1,2,2-Tetrachloroethane 1,1-Dichloroethene Carbon tetrachloride Chloroform Methylene chloride Trichloroethene			Nitrobenzene	Arsenic Mercury
6	Trichloroethene				
Outliers		Benzo(a)anthracene			

SVOC - Semivolatile organic compound.

VOC - Volatile organic compound.

Table 5-4

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 1**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 1 of 5)

UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
VOLATILES	1,1,1-Trichloroethane	OVB / INT	ND	ND	8	0	NA	0	200	0	0	0
	1,1,2,2-Tetrachloroethane	OVB / INT	ND	ND	8	0	NA	0	0.076	0	0	0
	1,1,2-Trichloroethane	OVB / INT	ND	ND	8	0	NA	0	5	0	0	0
	1,1-Dichloroethane	OVB / INT	ND	ND	8	0	NA	0	2.8	0	0	0
	1,1-Dichloroethene	OVB / INT	ND	ND	8	0	NA	0	7	0	0	0
	1,2,4-Trichlorobenzene	OVB / INT	ND	ND	4	0	NA	0	70	0	0	0
	1,2-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	600	0	0	0
	1,2-Dichloroethane	OVB / INT	ND	ND	8	0	NA	0	5	0	0	0
	1,2-Dichloropropane	OVB / INT	ND	ND	8	0	NA	0	5	0	0	0
	1,3-Dichlorobenzene	OVB / INT	ND	ND	3	0	NA	0	NA	0	0	0
	1,4-Dichlorobenzene	OVB / INT	ND	ND	4	0	NA	0	75	0	0	0
	2-Butanone	OVB / INT	ND	ND	8	0	NA	0	560	0	0	0
	2-Hexanone	OVB / INT	ND	ND	8	0	NA	0	3.8	0	0	0
	4-Methyl-2-pentanone	OVB / INT	ND	ND	8	0	NA	0	630	0	0	0
	Acetone	OVB / INT	2.5	2.5	7	1	NA	0	1400	0	14	0
	Benzene	OVB / INT	ND	ND	8	0	NA	0	5	0	0	0
	Bromodichloromethane	OVB / INT	ND	ND	8	0	NA	0	80	0	0	0
	Bromoform	OVB / INT	ND	ND	8	0	NA	0	80	0	0	0
	Bromomethane	OVB / INT	ND	ND	8	0	NA	0	0.75	0	0	0
	Carbon disulfide	OVB / INT	ND	ND	8	0	NA	0	81	0	0	0
	Carbon tetrachloride	OVB / INT	ND	ND	8	0	NA	0	5	0	0	0
	Chlorobenzene	OVB / INT	ND	ND	8	0	NA	0	100	0	0	0
	Chloroethane	OVB / INT	ND	ND	5	0	NA	0	2100	0	0	0
	Chloroform	OVB / INT	1.8	1.8	8	1	NA	0	80	0	13	0
	Chloromethane	OVB / INT	ND	ND	8	0	NA	0	19	0	0	0
	cis-1,2-Dichloroethene	OVB / INT	ND	ND	8	0	NA	0	70	0	0	0
	cis-1,3-Dichloropropene	OVB / INT	ND	ND	8	0	NA	0	0.47	0	0	0
	Dibromochloromethane	OVB / INT	ND	ND	8	0	NA	0	80	0	0	0
	Dichlorodifluoromethane	OVB / INT	ND	ND	4	0	NA	0	20	0	0	0
	Ethylbenzene	OVB / INT	ND	ND	8	0	NA	0	700	0	0	0
	Freon 113	OVB / INT	ND	ND	4	0	NA	0	1000	0	0	0
	Methyl tert-butyl ether	OVB / INT	ND	ND	4	0	NA	0	14	0	0	0
	Methylene chloride	OVB / INT	ND	ND	7	0	NA	0	5	0	0	0
	Styrene	OVB / INT	ND	ND	8	0	NA	0	100	0	0	0
	Tetrachloroethene	OVB / INT	ND	ND	8	0	NA	0	5	0	0	0
	Toluene	OVB / INT	0.16	0.41	8	2	NA	0	1000	0	25	0
	trans-1,2-Dichloroethene	OVB / INT	ND	ND	8	0	NA	0	100	0	0	0

Table 5-4

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 1

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	trans-1,3-Dichloropropene	OVB / INT	ND	ND	8	0	NA	0	0.47	0	0	0
	Trichloroethene	OVB / INT	0.53	32	8	8	NA	0	5	2	100	25
	Trichlorofluoromethane	OVB / INT	ND	ND	4	0	NA	0	520	0	0	0
	Vinyl chloride	OVB / INT	ND	ND	8	0	NA	0	2	0	0	0
	Xylene, Total	OVB / INT	ND	ND	8	0	NA	0	10000	0	0	0
SEMIVOLATILES	1,2-Dichlorobenzene	OVB / INT	ND	ND	3	0	NA	0	600	0	0	0
	1,3-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	NA	0	0	0
	1-Methylnaphthalene	OVB / INT	ND	ND	4	0	NA	0	1.1	0	0	0
	2,4,5-Trichlorophenol	OVB / INT	ND	ND	4	0	NA	0	120	0	0	0
	2,4,6-Trichlorophenol	OVB / INT	ND	ND	4	0	NA	0	1.2	0	0	0
	2,4-Dichlorophenol	OVB / INT	ND	ND	4	0	NA	0	4.6	0	0	0
	2,4-Dimethylphenol	OVB / INT	ND	ND	4	0	NA	0	36	0	0	0
	2,4-Dinitrophenol	OVB / INT	ND	ND	4	0	NA	0	3.9	0	0	0
	2,4-Dinitrotoluene	OVB / INT	ND	ND	3	0	NA	0	0.11	0	0	0
	2,6-Dinitrotoluene	OVB / INT	ND	ND	3	0	NA	0	0.11	0	0	0
	2-Chloronaphthalene	OVB / INT	ND	ND	4	0	NA	0	75	0	0	0
	2-Chlorophenol	OVB / INT	ND	ND	4	0	NA	0	9.1	0	0	0
	2-Methylnaphthalene	OVB / INT	ND	ND	4	0	NA	0	3.6	0	0	0
	2-Methylphenol	OVB / INT	ND	ND	4	0	NA	0	93	0	0	0
	2-Nitroaniline	OVB / INT	ND	ND	4	0	NA	0	19	0	0	0
	2-Nitrophenol	OVB / INT	ND	ND	4	0	NA	0	NA	0	0	0
	3-Nitroaniline	OVB / INT	ND	ND	4	0	NA	0	NA	0	0	0
	4-Bromophenyl phenyl ether	OVB / INT	ND	ND	4	0	NA	0	NA	0	0	0
	4-Chloro-3-methylphenol	OVB / INT	ND	ND	4	0	NA	0	140	0	0	0
	4-Chloroaniline	OVB / INT	ND	ND	4	0	NA	0	0.37	0	0	0
	4-Chlorophenyl phenyl ether	OVB / INT	ND	ND	4	0	NA	0	NA	0	0	0
	4-Methylphenol	OVB / INT	ND	ND	4	0	NA	0	190	0	0	0
	4-Nitroaniline	OVB / INT	ND	ND	4	0	NA	0	3.8	0	0	0
	4-Nitrophenol	OVB / INT	ND	ND	4	0	NA	0	NA	0	0	0
	Acenaphthene	OVB / INT	ND	ND	4	0	NA	0	53	0	0	0
	Acenaphthylene	OVB / INT	ND	ND	4	0	NA	0	47	0	0	0
	Anthracene	OVB / INT	ND	ND	4	0	NA	0	180	0	0	0
	Benzo(a)anthracene	OVB / INT	ND	ND	4	0	NA	0	0.03	0	0	0
	Benzo(a)pyrene	OVB / INT	0.11	0.11	4	1	NA	0	0.2	0	25	0
	Benzo(b)fluoranthene	OVB / INT	ND	ND	4	0	NA	0	0.25	0	0	0
	Benzo(ghi)perylene	OVB / INT	ND	ND	4	0	NA	0	60	0	0	0
	Benzo(k)fluoranthene	OVB / INT	ND	ND	4	0	NA	0	2.5	0	0	0

Table 5-4

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 1

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	bis(2-Chloroethoxy)methane	OVB / INT	ND	ND	4	0	NA	0	5.9	0	0	0
	bis(2-Chloroisopropyl)ether	OVB / INT	ND	ND	4	0	NA	0	71	0	0	0
	bis(2-Ethylhexyl)phthalate	OVB / INT	0.72	1.8	2	1	NA	0	6	0	50	0
	Butyl benzyl phthalate	OVB / INT	ND	ND	4	0	NA	0	16	0	0	0
	Carbazole	OVB / INT	ND	ND	4	0	NA	0	NA	0	0	0
	Chrysene	OVB / INT	ND	ND	4	0	NA	0	25	0	0	0
	Dibenzofuran	OVB / INT	ND	ND	4	0	NA	0	0.79	0	0	0
	Diethyl phthalate	OVB / INT	ND	ND	4	0	NA	0	1500	0	0	0
	Dimethyl phthalate	OVB / INT	ND	ND	4	0	NA	0	NA	0	0	0
	Di-n-butyl phthalate	OVB / INT	ND	ND	2	0	NA	0	90	0	0	0
	Di-n-octyl phthalate	OVB / INT	ND	ND	4	0	NA	0	20	0	0	0
	Fluoranthene	OVB / INT	ND	ND	4	0	NA	0	80	0	0	0
	Fluorene	OVB / INT	ND	ND	4	0	NA	0	29	0	0	0
	Hexachlorobenzene	OVB / INT	ND	ND	4	0	NA	0	1	0	0	0
	Hexachlorobutadiene	OVB / INT	ND	ND	4	0	NA	0	0.14	0	0	0
	Hexachlorocyclopentadiene	OVB / INT	ND	ND	4	0	NA	0	50	0	0	0
	Hexachloroethane	OVB / INT	ND	ND	4	0	NA	0	0.33	0	0	0
	Indeno(1,2,3-cd)pyrene	OVB / INT	ND	ND	4	0	NA	0	0.25	0	0	0
	Isophorone	OVB / INT	ND	ND	4	0	NA	0	78	0	0	0
	Naphthalene	OVB / INT	ND	ND	4	0	NA	0	0.17	0	0	0
	Nitrobenzene	OVB / INT	ND	ND	4	0	NA	0	0.14	0	0	0
	n-Nitrosodiphenylamine	OVB / INT	ND	ND	4	0	NA	0	12	0	0	0
	Pentachlorophenol	OVB / INT	ND	ND	4	0	NA	0	1	0	0	0
	Phenanthrene	OVB / INT	ND	ND	4	0	NA	0	18	0	0	0
	Phenol	OVB / INT	ND	ND	4	0	NA	0	580	0	0	0
	Pyrene	OVB / INT	ND	ND	4	0	NA	0	12	0	0	0
PESTICIDES/PCBS	4,4'-DDD	OVB / INT	ND	ND	1	0	NA	0	0.032	0	0	0
	4,4'-DDE	OVB / INT	ND	ND	1	0	NA	0	0.046	0	0	0
	4,4'-DDT	OVB / INT	ND	ND	1	0	NA	0	0.23	0	0	0
	Aldrin	OVB / INT	ND	ND	1	0	NA	0	0.00092	0	0	0
	alpha-BHC	OVB / INT	ND	ND	1	0	NA	0	0.0072	0	0	0
	alpha-Chlordane	OVB / INT	ND	ND	1	0	NA	0	2	0	0	0
	beta-BHC	OVB / INT	ND	ND	1	0	NA	0	0.025	0	0	0
	delta-BHC	OVB / INT	ND	ND	1	0	NA	0	0.36	0	0	0
	Dieldrin	OVB / INT	ND	ND	1	0	NA	0	0.0018	0	0	0
	Endosulfan I	OVB / INT	ND	ND	1	0	NA	0	10	0	0	0
	Endosulfan II	OVB / INT	ND	ND	1	0	NA	0	10	0	0	0



Table 5-4

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 1

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Endosulfan sulfate	OVB / INT	ND	ND	1	0	NA	0	10	0	0	0
	Endrin	OVB / INT	ND	ND	1	0	NA	0	2	0	0	0
	Endrin aldehyde	OVB / INT	ND	ND	1	0	NA	0	0.23	0	0	0
	Endrin ketone	OVB / INT	ND	ND	1	0	NA	0	0.23	0	0	0
	gamma-BHC (Lindane)	OVB / INT	ND	ND	1	0	NA	0	0.2	0	0	0
	gamma-Chlordane	OVB / INT	ND	ND	1	0	NA	0	2	0	0	0
	Heptachlor	OVB / INT	ND	ND	1	0	NA	0	0.4	0	0	0
	Heptachlor epoxide	OVB / INT	ND	ND	1	0	NA	0	0.2	0	0	0
	Methoxychlor	OVB / INT	ND	ND	1	0	NA	0	40	0	0	0
	Toxaphene	OVB / INT	ND	ND	1	0	NA	0	3	0	0	0
EXPLOSIVES	1,3,5-Trinitrobenzene	OVB / INT	ND	ND	1	0	NA	0	59	0	0	0
	1,3-Dinitrobenzene	OVB / INT	ND	ND	1	0	NA	0	0.2	0	0	0
	2,4,6-Trinitrotoluene	OVB / INT	ND	ND	1	0	NA	0	0.98	0	0	0
	2,4-Dinitrotoluene	OVB / INT	ND	ND	1	0	NA	0	0.11	0	0	0
	2,6-Dinitrotoluene	OVB / INT	ND	ND	1	0	NA	0	0.11	0	0	0
	2-Amino-4,6-dinitrotoluene	OVB / INT	ND	ND	1	0	NA	0	3.9	0	0	0
	2-Nitrotoluene	OVB / INT	ND	ND	1	0	NA	0	0.31	0	0	0
	3-Nitrotoluene	OVB / INT	ND	ND	1	0	NA	0	0.17	0	0	0
	4-Amino-2,6-dinitrotoluene	OVB / INT	ND	ND	1	0	NA	0	3.9	0	0	0
	HMX	OVB / INT	ND	ND	1	0	NA	0	100	0	0	0
	Nitrobenzene	OVB / INT	ND	ND	1	0	NA	0	0.14	0	0	0
	Nitroglycerin	OVB / INT	ND	ND	1	0	NA	0	0.2	0	0	0
	PETN	OVB / INT	ND	ND	1	0	NA	0	3.9	0	0	0
	p-Nitrotoluene	OVB / INT	ND	ND	1	0	NA	0	4.3	0	0	0
	RDX	OVB / INT	ND	ND	1	0	NA	0	0.7	0	0	0
	Tetryl	OVB / INT	ND	ND	1	0	NA	0	3.9	0	0	0
METALS	Aluminum	OVB / INT	15	481	7	6	9434	0	2000	0	86	0
	Antimony	OVB / INT	ND	ND	7	0	17	0	6	0	0	0
	Arsenic	OVB / INT	0.67	4.33	7	2	5.1	0	10	0	29	0
	Barium	OVB / INT	3.4	18	7	7	156	0	2000	0	100	0
	Beryllium	OVB / INT	1.4	1.4	7	2	5	0	4	0	29	0
	Cadmium	OVB / INT	0.92	0.92	7	1	5	0	5	0	14	0
	Calcium	OVB / INT	2300	59100	7	7	144000	0	NA	0	100	0
	Chromium	OVB / INT	0.5	2.6	7	5	16	0	100	0	71	0
	Cobalt	OVB / INT	0.28	0.28	7	1	50	0	0.6	0	14	0
	Copper	OVB / INT	0.73	33	7	4	25	1	1300	0	57	0
	Iron	OVB / INT	81	378	7	3	12100	0	1400	0	43	0

Table 5-4

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 1

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Lead	OVB / INT	0.28	1.7	7	4	5.2	0	15	0	57	0
	Magnesium	OVB / INT	200	5300	7	7	19414	0	NA	0	100	0
	Manganese	OVB / INT	2.2	29	7	6	3220	0	43	0	86	0
	Mercury	OVB / INT	0.14	1.15	7	2	0.2	1	2	0	29	0
	Nickel	OVB / INT	0.5	2.9	7	4	40	0	100	0	57	0
	Potassium	OVB / INT	370	3100	7	4	5810	0	NA	0	57	0
	Selenium	OVB / INT	ND	ND	7	0	5	0	50	0	0	0
	Silver	OVB / INT	0.24	0.98	7	3	10	0	9.4	0	43	0
	Sodium	OVB / INT	1100	21000	7	7	65600	0	NA	0	100	0
	Thallium	OVB / INT	ND	ND	7	0	5.7	0	2	0	0	0
	Vanadium	OVB / INT	0.82	0.82	7	1	50	0	8.6	0	14	0
	Zinc	OVB / INT	5.7	28	7	6	211	0	600	0	86	0

µg/L - Micrograms per liter.

BSV - Background screening value.

MR - Most recent.

PSV - Preliminary screening value.

UTG - User test group.

<sup>(1)</sup> The Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:1) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).2) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017, *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, June, <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017>).The health advisory level is used for perchlorate (DoD, 2009, *Perchlorate Release Management Policy*, Memorandum from Wayne Army to Deputy Assistant Secretaries of the Army, Navy, and Air Force, 4 April).<sup>(2)</sup> Ratio of detected concentrations in usable samples to the total number of samples collected.<sup>(3)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of usable samples analyzed.

Table 5-5

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 2**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections In Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
VOLATILES	1,1,1-Trichloroethane	OV8-S	ND	ND	20	0	NA	0	200	0	0	0
		OV8 / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,1,2,2-Tetrachloroethane	OV8-S	ND	ND	20	0	NA	0	0.076	0	0	0
		OV8 / INT	0.55	0.55	34	1		0		1	2.9	2.9
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,1,2-Trichloroethane	OV8-S	ND	ND	20	0	NA	0	5	0	0	0
		OV8 / INT	0.48	1.1	34	2		0		0	5.9	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,1-Dichloroethane	OV8-S	ND	ND	20	0	NA	0	2.8	0	0	0
		OV8 / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,1-Dichloroethene	OV8-S	ND	ND	20	0	NA	0	7	0	0	0
		OV8 / INT	0.743	0.743	34	1		0		0	2.9	0
		BR	0.49	0.55	8	2		0		0	25	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,2,4-Trichlorobenzene	OV8-S	ND	ND	17	0	NA	0	70	0	0	0
		OV8 / INT	ND	ND	27	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,2-Dichlorobenzene	OV8-S	ND	ND	15	0	NA	0	600	0	0	0
		OV8 / INT	ND	ND	23	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,2-Dichloroethane	OV8-S	ND	ND	20	0	NA	0	5	0	0	0
		OV8 / INT	ND	ND	34	0		0		0	0	0
		BR	0.64	1.4	8	3		0		0	38	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,2-Dichloropropane	OV8-S	ND	ND	20	0	NA	0	5	0	0	0
		OV8 / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	1,3-Dichlorobenzene	OV-B-S	ND	ND	16	0	NA	0	NA	0	0	0
		OV-B / INT	ND	ND	26	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,4-Dichlorobenzene	OV-B-S	ND	ND	17	0	NA	0	75	0	0	0
		OV-B / INT	ND	ND	27	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Butanone	OV-B-S	ND	ND	20	0	NA	0	560	0	0	0
		OV-B / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	1.7	1.7	1	1		0		0	100	0
	2-Hexanone	OV-B-S	ND	ND	20	0	NA	0	3.8	0	0	0
		OV-B / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4-Methyl-2-pentanone	OV-B-S	ND	ND	20	0	NA	0	630	0	0	0
		OV-B / INT	ND	ND	34	0		0		0	0	0
		BR	1	1	8	1		0		0	13	0
		BR-D	ND	ND	1	0		0		0	0	0
	Acetone	OV-B-S	1.76	4.3	20	5	NA	0	1400	0	25	0
		OV-B / INT	1.1	2.7	34	2		0		0	5.9	0
		BR	1.3	64	7	5		0		0	71	0
		OV-B-S	ND	ND	20	0		0		0	0	0
	Benzene	OV-B / INT	ND	ND	34	0	NA	0	5	0	0	0
		BR	0.4	0.43	8	2		0		0	25	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	20	0		0		0	0	0
	Bromodichloromethane	OV-B / INT	ND	ND	34	0	NA	0	80	0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	20	0		0		0	0	0
	Bromoform	OV-B / INT	ND	ND	34	0	NA	0	80	0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	20	0		0		0	0	0

Table 5-5

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 2**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Bromomethane	OV-B-S	ND	ND	20	0	NA	0	0.75	0	0	0
		OV-B / INT	5	5	34	1		0		1	2.9	2.9
		BR	ND	ND	8	0		0		0	0	0
	Carbon disulfide	BR-D	ND	ND	1	0	NA	0	81	0	0	0
		OV-B-S	0.67	3.4	17	6		0		0	35	0
		OV-B / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Carbon tetrachloride	BR-D	2.4	2.4	1	1	NA	0	5	0	100	0
		OV-B-S	ND	ND	20	0		0		0	0	0
		OV-B / INT	0.4	1.7	34	4		0		0	12	0
		BR	ND	ND	8	0		0		0	0	0
	Chlorobenzene	BR-D	ND	ND	1	0	NA	0	100	0	0	0
		OV-B-S	ND	ND	20	0		0		0	0	0
		OV-B / INT	0.24	7.1	34	5		0		0	15	0
		BR	0.38	0.38	8	1		0		0	13	0
	Chloroethane	BR-D	7.5	7.5	1	1	NA	0	2100	0	100	0
		OV-B-S	ND	ND	20	0		0		0	0	0
		OV-B / INT	ND	ND	32	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
	Chloroform	BR-D	ND	ND	1	0	NA	0	80	0	0	0
		OV-B-S	0.35	7.4	20	8		0		0	40	0
		OV-B / INT	0.19	21	33	16		0		0	48	0
		BR	0.13	0.13	8	1		0		0	13	0
	Chloromethane	BR-D	ND	ND	1	0	NA	0	19	0	0	0
		OV-B-S	ND	ND	20	0		0		0	0	0
		OV-B / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
	cis-1,2-Dichloroethene	BR-D	ND	ND	1	0	NA	0	70	0	0	0
		OV-B-S	0.19	2.8	20	3		0		0	15	0
		OV-B / INT	0.2	6	34	5		0		0	15	0
		BR	0.76	1.7	8	3		0		0	38	0
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	cis-1,3-Dichloropropene	OVb-S	ND	ND	20	0	NA	0	0.47	0	0	0
		OVb / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Dibromochloromethane	OVb-S	ND	ND	20	0	NA	0	80	0	0	0
		OVb / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Dichlorodifluoromethane	OVb-S	ND	ND	17	0	NA	0	20	0	0	0
		OVb / INT	ND	ND	27	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Ethylbenzene	OVb-S	ND	ND	20	0	NA	0	700	0	0	0
		OVb / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Freon 113	OVb-S	ND	ND	17	0	NA	0	1000	0	0	0
		OVb / INT	0.46	14	27	9		0		0	33	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Methyl tert-butyl ether	OVb-S	ND	ND	17	0	NA	0	14	0	0	0
		OVb / INT	ND	ND	27	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	0.22	0.22	1	1		0		0	100	0
	Methylene chloride	OVb-S	ND	ND	18	0	NA	0	5	0	0	0
		OVb / INT	0.36	0.36	32	1		0		0	3.1	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Styrene	OVb-S	ND	ND	20	0	NA	0	100	0	0	0
		OVb / INT	ND	ND	34	0		0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Tetrachloroethene	OVb-S	1.3	1.3	20	1	NA	0	5	0	5	0
		OVb / INT	0.62	8.6	34	8		0		1	24	2.9
		BR	0.4	1.2	8	2		0		0	25	0
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Toluene	OV-B-S	ND	ND	20	0	NA	0	1000	0	0	0
		OV-B / INT	0.18	0.59	34	2		0		0	5.9	0
		BR	7.9	7.9	8	1		0		0	13	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	20	0		0	100	0	0	0
		OV-B / INT	ND	ND	34	0		0		0	0	0
	trans-1,2-Dichloroethene	BR	ND	ND	8	0	NA	0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	20	0		0		0	0	0
		OV-B / INT	ND	ND	34	0		0	0.47	0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	trans-1,3-Dichloropropene	OV-B-S	ND	ND	20	0		0	5	5	60	25
		OV-B / INT	0.45	2.7	34	14	NA	0		0	41	0
		BR	0.24	25	8	6		0		2	75	25
	Trichloroethene	BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	17	0		0	520	0	0	0
		OV-B / INT	0.43	8	27	3	NA	0		0	11	0
	Trichlorofluoromethane	BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0	2	0	0	0
		OV-B-S	ND	ND	20	0		0		0	0	0
	Vinyl chloride	OV-B / INT	ND	ND	34	0	NA	0		0	0	0
		BR	ND	ND	8	0		0	10000	0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Xylene, Total	OV-B-S	ND	ND	20	0		0		0	0	0
		OV-B / INT	ND	ND	34	0	NA	0		0	0	0
		BR	ND	ND	8	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
SEMIVOLATILES	1,2,4-Trichlorobenzene	OV-B / INT	ND	ND	1	0	NA	0	70	0	0	0
		BR	ND	ND	1	0		0		0	0	0
	1,2-Dichlorobenzene	OV-B-S	ND	ND	2	0	NA	0	600	0	0	0
		OV-B / INT	ND	ND	5	0		0		0	0	0
	1,3-Dichlorobenzene	BR	ND	ND	1	0		0	NA	0	0	0
		OV-B-S	ND	ND	1	0		0		0	0	0
		OV-B / INT	ND	ND	2	0	NA	0		0	0	0
		BR	ND	ND	1	0		0		0	0	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	1,4-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	75	0	0	0
		BR	ND	ND	1	0		0		0	0	0
	1-Methylnaphthalene	OVB-S	ND	ND	5	0	NA	0	1.1	0	0	0
		OVB / INT	ND	ND	26	0		0		0	0	0
		BR	ND	ND	2	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OVB-S	ND	ND	6	0		0		0	0	0
	2,4,5-Trichlorophenol	OVB / INT	ND	ND	28	0	NA	0	120	0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2,4,6-Trichlorophenol	OVB-S	ND	ND	6	0	NA	0	1.2	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2,4-Dichlorophenol	OVB-S	ND	ND	6	0	NA	0	4.6	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2,4-Dimethylphenol	OVB-S	ND	ND	6	0	NA	0	36	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2,4-Dinitrophenol	OVB-S	ND	ND	6	0	NA	0	3.9	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2,4-Dinitrotoluene	OVB-S	ND	ND	5	0	NA	0	0.11	0	0	0
		OVB / INT	ND	ND	25	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2,6-Dinitrotoluene	OVB-S	ND	ND	5	0	NA	0	0.11	0	0	0
		OVB / INT	1.3	1.3	25	1		0		1	4	4
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0



Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 2

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Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections In Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	2-Chloronaphthalene	OV-B-S	ND	ND	7	0	NA	0	75	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Chlorophenol	OV-B-S	ND	ND	6	0	NA	0	9.1	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Methylnaphthalene	OV-B-S	0.04	0.04	7	1	NA	0	3.6	0	14	0
		OV-B / INT	0.04	0.06	28	3		0		0	11	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Methylphenol	OV-B-S	ND	ND	6	0	NA	0	93	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	0.74	0.74	3	1		0		0	33	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Nitroaniline	OV-B-S	ND	ND	7	0	NA	0	19	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Nitrophenol	OV-B-S	ND	ND	6	0	NA	0	NA	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	3,3'-Dichlorobenzidine	OV-B-S	ND	ND	5	0	NA	0	0.13	0	0	0
		OV-B / INT	ND	ND	8	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	3-Nitroaniline	OV-B-S	ND	ND	7	0	NA	0	NA	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4,6-Dinitro-2-methylphenol	OV-B-S	ND	ND	3	0	NA	0	0.15	0	0	0
		OV-B / INT	ND	ND	5	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	4-Bromophenyl phenyl ether	OVb-S	ND	ND	7	0	NA	0	NA	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4-Chloro-3-methylphenol	OVb-S	ND	ND	6	0	NA	0	140	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4-Chloroaniline	OVb-S	ND	ND	7	0	NA	0	0.37	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4-Chlorophenyl phenyl ether	OVb-S	ND	ND	7	0	NA	0	NA	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4-Methylphenol	OVb-S	ND	ND	6	0	NA	0	190	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4-Nitroaniline	OVb-S	ND	ND	7	0	NA	0	3.8	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	4-Nitrophenol	OVb-S	ND	ND	6	0	NA	0	NA	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Acenaphthene	OVb-S	ND	ND	7	0	NA	0	53	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Acenaphthylene	OVb-S	ND	ND	7	0	NA	0	47	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-5

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 2**  
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**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections In Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Anthracene	OV-B-S	0.07	0.07	7	1	NA	0	180	0	14	0
		OV-B / INT	0.06	0.06	28	1		0		0	3.6	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Benzo(a)anthracene	OV-B-S	0.27	0.27	5	1	NA	0	0.03	1	20	20
		OV-B / INT	0.1	0.23	26	2		0		2	7.7	7.7
		BR	ND	ND	2	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Benzo(a)pyrene	OV-B-S	0.28	0.28	7	1	NA	0	0.2	1	14	14
		OV-B / INT	0.17	0.17	28	1		0		0	3.6	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Benzo(b)fluoranthene	OV-B-S	0.22	0.22	5	1	NA	0	0.25	0	20	0
		OV-B / INT	0.19	0.19	26	1		0		0	3.8	0
		BR	ND	ND	2	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Benzo(ghi)perylene	OV-B-S	0.22	0.22	7	1	NA	0	60	0	14	0
		OV-B / INT	0.18	0.18	28	1		0		0	3.6	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Benzo(k)fluoranthene	OV-B-S	0.28	0.28	7	1	NA	0	2.5	0	14	0
		OV-B / INT	0.21	0.21	28	1		0		0	3.6	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	bis(2-Chloroethoxy)methane	OV-B-S	ND	ND	7	0	NA	0	5.9	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	bis(2-Chloroethyl)ether	OV-B / INT	ND	ND	1	0	NA	0	0.014	0	0	0
		OV-B-S	ND	ND	7	0		0		0	0	0
	bis(2-Chloroisopropyl)ether	OV-B / INT	ND	ND	28	0	NA	0	71	0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	0.67	44	6	4	NA	0	6	1	67	17
	bis(2-Ethylhexyl)phthalate	OV-B / INT	0.36	15	25	11		0		5	44	20
		BR	ND	ND	3	0		0		0	0	0
		BR-D	0.38	0.38	1	1		0		0	100	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Butyl benzyl phthalate	OVb-S	ND	ND	7	0	NA	0	16	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Carbazole	OVb-S	0.2	0.2	7	1	NA	0	NA	0	14	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Chrysene	OVb-S	0.24	0.24	7	1	NA	0	25	0	14	0
		OVb / INT	0.11	0.17	28	2		0		0	7.1	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Dibenz(a,h)anthracene	OVb-S	0.23	0.23	1	1	NA	0	0.025	1	100	100
		OVb / INT	0.14	0.14	3	1		0		1	33	33
	Dibenzofuran	OVb-S	ND	ND	7	0	NA	0	0.79	0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
	Diethyl phthalate	BR-D	ND	ND	1	0	NA	0	1500	0	0	0
		OVb-S	ND	ND	7	0		0		0	0	0
		OVb / INT	ND	ND	23	0		0		0	0	0
		BR	ND	ND	2	0		0		0	0	0
	Dimethyl phthalate	BR-D	ND	ND	1	0	NA	0	NA	0	0	0
		OVb-S	ND	ND	7	0		0		0	0	0
		OVb / INT	0.19	0.2	28	2		0		0	7.1	0
	Di-n-butyl phthalate	BR	ND	ND	3	0	NA	0	90	0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OVb-S	0.34	1.2	7	2		0		0	29	0
		OVb / INT	0.23	0.4	23	4		0		0	17	0
	Di-n-octyl phthalate	BR	ND	ND	3	0	NA	0	20	0	0	0
		BR-D	0.26	0.26	1	1		0		0	100	0
		OVb-S	ND	ND	7	0		0		0	0	0
		OVb / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0	NA	0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-5

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 2**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections In Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Fluoranthene	OVB-S	0.14	0.14	7	1	NA	0	80	0	14	0
		OVB / INT	0.11	0.11	28	1		0		0	3.6	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Fluorene	OVB-S	ND	ND	7	0	NA	0	29	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Hexachlorobenzene	OVB-S	ND	ND	7	0	NA	0	1	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Hexachlorobutadiene	OVB-S	ND	ND	7	0	NA	0	0.14	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Hexachlorocyclopentadiene	OVB-S	ND	ND	7	0	NA	0	50	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Hexachloroethane	OVB-S	ND	ND	7	0	NA	0	0.33	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Indeno(1,2,3-cd)pyrene	OVB-S	0.24	0.24	5	1	NA	0	0.25	0	20	0
		OVB / INT	0.18	0.18	26	1		0		0	3.8	0
		BR	ND	ND	2	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Isophorone	OVB-S	ND	ND	7	0	NA	0	78	0	0	0
		OVB / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Naphthalene	OVB-S	0.64	0.64	7	1	NA	0	0.17	1	14	14
		OVB / INT	0.14	0.15	28	2		0		0	7.1	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Nitrobenzene	OV-B-S	ND	ND	7	0	NA	0	0.14	0	0	0
		OV-B / INT	ND	ND	28	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	n-Nitroso-di-n-propylamine	OV-B / INT	ND	ND	1	0	NA	0	0.011	0	0	0
		OV-B-S	ND	ND	7	0		0		0	0	0
	n-Nitrosodiphenylamine	OV-B / INT	ND	ND	28	0	NA	0	12	0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
	Pentachlorophenol	OV-B / INT	ND	ND	28	0	NA	0	1	0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	0.09	0.09	7	1		0		0	14	0
	Phenanthrene	OV-B / INT	0.07	0.08	28	2	NA	0	18	0	7.1	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
	Phenol	OV-B / INT	0.29	0.29	25	1	NA	0	580	0	0	0
		BR	3.4	3.4	3	1		0		0	33	0
		BR-D	2	2	1	1		0		0	100	0
		OV-B-S	0.15	0.15	7	1		0		0	14	0
	Pyrene	OV-B / INT	0.14	0.14	28	1	NA	0	12	0	3.6	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
EXPLOSIVES	1,3,5-Trinitrobenzene	OV-B-S	ND	ND	2	0	NA	0	59	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	1,3-Dinitrobenzene	OV-B-S	ND	ND	2	0	NA	0	0.2	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	2,4,6-Trinitrotoluene	OV-B-S	ND	ND	2	0	NA	0	0.98	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	2,4-Dinitrotoluene	OV-B-S	ND	ND	2	0	NA	0	0.11	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	2,6-Dinitrotoluene	OV-B-S	ND	ND	2	0	NA	0	0.11	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	2-Amino-4,6-dinitrotoluene	OV-B-S	ND	ND	2	0	NA	0	3.9	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0

Table 5-5

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 2**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	2-Nitrotoluene	OV-B-S	ND	ND	2	0	NA	0	0.31	0	0	0
		OV-B / INT	0.14	0.14	3	1		0		0	33	0
	3-Nitrotoluene	OV-B-S	ND	ND	2	0	NA	0	0.17	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	4-Amino-2,6-dinitrotoluene	OV-B-S	ND	ND	2	0	NA	0	3.9	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	HMX	OV-B-S	ND	ND	2	0	NA	0	100	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	Nitrobenzene	OV-B-S	ND	ND	2	0	NA	0	0.14	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	Nitroglycerin	OV-B-S	ND	ND	2	0	NA	0	0.2	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	PETN	OV-B-S	ND	ND	2	0	NA	0	3.9	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	p-Nitrotoluene	OV-B-S	ND	ND	2	0	NA	0	4.3	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	RDX	OV-B-S	ND	ND	2	0	NA	0	0.7	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
	Tetryl	OV-B-S	ND	ND	2	0	NA	0	3.9	0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
METALS	Aluminum	OV-B-S	4.6	618	17	17	9434	0	2000	0	100	0
		OV-B / INT	4.1	1690	28	26		0		0	93	0
		BR	ND	ND	1	0		0		0	0	0
	Antimony	OV-B-S	0.57	4.6	17	6	17	0	6	0	35	0
		OV-B / INT	0.8	1.4	28	2		0		0	7.1	0
		BR	ND	ND	1	0		0		0	0	0
	Arsenic	OV-B-S	0.73	3470	20	13	5.1	8	10	7	65	35
		OV-B / INT	0.65	2800	34	22		8		4	65	12
		BR	1.42	1.42	6	1		0		0	17	0
		BR-D	ND	ND	1	0		0		0	0	0
	Barium	OV-B-S	12.9	120	17	17	156	0	2000	0	100	0
		OV-B / INT	6.6	82	28	28		0		0	100	0
		BR	162	162	1	1		1		0	100	0
	Beryllium	OV-B-S	0.44	0.44	17	1	5	0	4	0	5.9	0
		OV-B / INT	0.28	0.48	28	5		0		0	18	0
		BR	ND	ND	1	0		0		0	0	0

Table 5-5

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 2

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections In Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Cadmium	OVBS	0.97	0.97	17	1	5	0	5	0	5.9	0
		OVBS / INT	0.31	1.3	28	7		0		0	25	0
		BR	ND	ND	1	0		0		0	0	0
	Calcium	OVBS	3840	120000	17	17	144000	0	NA	0	100	0
		OVBS / INT	4600	140000	28	28		0		0	100	0
		BR	27900	28000	2	2		0		0	100	0
	Chromium	OVBS	0.32	2.2	17	13	16	0	100	0	76	0
		OVBS / INT	0.49	4.65	28	19		0		0	68	0
		BR	ND	ND	1	0		0		0	0	0
	Cobalt	OVBS	0.14	10.9	17	16	50	0	0.6	8	94	0
		OVBS / INT	0.18	32	28	22		0		11	79	0
		BR	ND	ND	1	0		0		0	0	0
	Copper	OVBS	0.86	11	17	17	25	0	1300	0	100	0
		OVBS / INT	0.48	9.8	28	23		0		0	82	0
		BR	ND	ND	1	0		0		0	0	0
	Iron	OVBS	69.2	5320	17	12	12100	0	1400	4	71	0
		OVBS / INT	38.4	1600	28	16		0		1	57	0
		BR	69.7	69.7	2	1		0		0	50	0
	Lead	OVBS	0.34	1.76	17	12	5.2	0	15	0	71	0
		OVBS / INT	0.25	2.2	28	12		0		0	43	0
		BR	ND	ND	1	0		0		0	0	0
	Magnesium	OVBS	491	5830	17	17	19414	0	NA	0	100	0
		OVBS / INT	870	8700	28	26		0		0	93	0
		BR	16200	22000	2	2		1		0	100	0
	Manganese	OVBS	1	4500	17	17	3220	2	43	11	100	12
		OVBS / INT	0.86	3000	28	28		0		16	100	0
		BR	3.9	4.6	2	2		0		0	100	0
	Mercury	OVBS	ND	ND	17	0	0.2	0	2	0	0	0
		OVBS / INT	ND	ND	29	0		0		0	0	0
		BR	ND	ND	3	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Nickel	OVBS	0.58	7.99	17	17	40	0	100	0	100	0
		OVBS / INT	0.88	12	28	25		0		0	89	0
		BR	8.5	8.5	1	1		0		0	100	0
	Potassium	OVBS	150	1450	17	17	5810	0	NA	0	100	0
		OVBS / INT	130	4000	28	22		0		0	79	0
		BR	5070	24000	2	2		1		0	100	0



Table 5-5

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 2**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Selenium	OVB-S	1.52	5	17	10	5	0	50	0	59	0
		OVB / INT	1.5	2.9	28	8		0		0	29	0
		BR	ND	ND	1	0		0		0	0	0
	Silver	OVB-S	0.19	0.3	17	2	10	0	9.4	0	12	0
		OVB / INT	0.2	0.58	28	8		0		0	29	0
		BR	ND	ND	1	0		0		0	0	0
	Sodium	OVB-S	3400	180000	17	17	65600	1	NA	0	100	0
		OVB / INT	970	23100	28	28		0		0	100	0
		BR	13700	17000	2	2		0		0	100	0
	Thallium	OVB-S	0.18	0.32	17	4	5.7	0	2	0	24	0
		OVB / INT	0.24	1.6	27	6		0		0	22	0
		BR	ND	ND	1	0		0		0	0	0
	Vanadium	OVB-S	0.55	2.9	17	14	50	0	8.6	0	82	0
		OVB / INT	0.51	2.2	28	15		0		0	54	0
		BR	ND	ND	1	0		0		0	0	0
	Zinc	OVB-S	7.55	50.9	15	14	211	0	600	0	93	0
		OVB / INT	4.4	100	28	26		0		0	93	0
		BR	12.6	12.6	1	1		0		0	100	0

µg/L - Micrograms per liter.

BSV - Background screening value.

MR - Most recent.

PSV - Preliminary screening value.

UTG - User test group.

<sup>(1)</sup> The Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:1) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).2) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017 *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, June, <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017>). The health advisory level is used for perchlorate (DoD, 2009, *Perchlorate Release Management Policy*, Memorandum from Wayne Army to Deputy Assistant Secretaries of the Army, Navy, and Air Force, 4 April).<sup>(2)</sup> Ratio of detected concentrations in usable samples to the total number of samples collected.<sup>(3)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of usable samples analyzed.

Table 5-6

**Analytical Summary, Deep Flow Zone Locations, Focus Areas 1 and 2  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F122-RS513	126.4	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	UJ
			Bromomethane	0.75	NA	5	UJ
			Tetrachloroethene	5	NA	1	UJ
			Trichloroethene	5	NA	1	UJ
		SVOCs	Benzo(a)anthracene	0.03	NA	0.2	U
			Benzo(a)pyrene	0.2	NA	0.2	UJ
			bis(2-Ethylhexyl)phthalate	6	NA	0.38	J
			Naphthalene	0.17	NA	0.2	U
		Metals	Arsenic	10	5.1	1	U
F54-RS300	129.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			Bromomethane	0.75	NA	2	U
			Tetrachloroethene	5	NA	1	U
			Trichloroethene	5	NA	1	U
		Metals	Arsenic	10	5.1	10	U
			Manganese	43	3220	19.1	
F54-RS301	143.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			Bromomethane	0.75	NA	2	U
			Tetrachloroethene	5	NA	1	U
			Trichloroethene	5	NA	1	U
F54-RS302	146	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			Bromomethane	0.75	NA	2	U
			Tetrachloroethene	5	NA	1	U
			Trichloroethene	5	NA	1	U
F55-RS1063	161.75	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			Bromomethane	0.75	NA	2	UJ
			Tetrachloroethene	5	NA	1	U
			Trichloroethene	5	NA	1.6	
Z-RS1230D	140	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			Bromomethane	0.75	NA	2	UJ
			Tetrachloroethene	5	NA	1	U
			Trichloroethene	5	NA	1	U
Z-RS1236D	147	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			Bromomethane	0.75	NA	2	U
			Tetrachloroethene	5	NA	1	U
			Trichloroethene	5	NA	1	U
		SVOCs	Benzo(a)anthracene	0.03	NA	1.96	U
			Benzo(a)pyrene	0.2	NA	1.96	U
			Dibenz(a,h)anthracene	0.025	NA	1.96	U
			Naphthalene	0.17	NA	1.96	U

Table 5-7

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 3**  
**RSA-147/148/149**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
VOLATILES	1,1,1-Trichloroethane	OVB-S	ND	ND	3	0	NA	0	200	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	1,1,2,2-Tetrachloroethane	OVB-S	ND	ND	3	0	NA	0	0.076	0	0	0
		OVB / INT	5.61	5.61	2	1		0		1	50	50
	1,1,2-Trichloroethane	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	1,1-Dichloroethane	OVB-S	ND	ND	3	0	NA	0	2.8	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	1,1-Dichloroethene	OVB-S	ND	ND	3	0	NA	0	7	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	1,2,4-Trichlorobenzene	OVB-S	ND	ND	2	0	NA	0	70	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	1,2-Dichlorobenzene	OVB-S	ND	ND	2	0	NA	0	600	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	1,2-Dichloroethane	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	1,2-Dichloropropane	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	1,3-Dichlorobenzene	OVB-S	ND	ND	2	0	NA	0	NA	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	1,4-Dichlorobenzene	OVB-S	ND	ND	2	0	NA	0	75	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	2-Butanone	OVB-S	ND	ND	3	0	NA	0	560	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	2-Hexanone	OVB-S	ND	ND	3	0	NA	0	3.8	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	4-Methyl-2-pentanone	OVB-S	ND	ND	3	0	NA	0	630	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Acetone	OVB-S	ND	ND	3	0	NA	0	1400	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Benzene	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Bromodichloromethane	OVB-S	ND	ND	3	0	NA	0	80	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Bromoform	OVB-S	ND	ND	3	0	NA	0	80	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Bromomethane	OVB-S	ND	ND	3	0	NA	0	0.75	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Carbon disulfide	OVB-S	ND	ND	3	0	NA	0	81	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Carbon tetrachloride	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	27.6	27.6	2	1		0		1	50	50

Table 5-7

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Chlorobenzene	OVB-S	ND	ND	3	0	NA	0	100	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Chloroethane	OVB-S	ND	ND	2	0		0	2100	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Chloroform	OVB-S	ND	ND	3	0	NA	0	80	0	0	0
		OVB / INT	2.36	2.36	2	1		0		0	50	0
	Chloromethane	OVB-S	ND	ND	3	0	NA	0	19	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	cis-1,2-Dichloroethene	OVB-S	ND	ND	3	0	NA	0	70	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	cis-1,3-Dichloropropene	OVB-S	ND	ND	3	0	NA	0	0.47	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Dibromochloromethane	OVB-S	ND	ND	3	0	NA	0	80	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Dichlorodifluoromethane	OVB-S	ND	ND	2	0	NA	0	20	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Ethylbenzene	OVB-S	ND	ND	3	0	NA	0	700	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Freon 113	OVB-S	ND	ND	2	0	NA	0	1000	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Methyl tert-butyl ether	OVB-S	ND	ND	2	0	NA	0	14	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Methylene chloride	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Styrene	OVB-S	ND	ND	3	0	NA	0	100	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Tetrachloroethene	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Toluene	OVB-S	ND	ND	3	0	NA	0	1000	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	trans-1,2-Dichloroethene	OVB-S	ND	ND	3	0	NA	0	100	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	trans-1,3-Dichloropropene	OVB-S	ND	ND	3	0	NA	0	0.47	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Trichloroethene	OVB-S	ND	ND	3	0	NA	0	5	0	0	0
		OVB / INT	8.53	8.53	2	1		0		1	50	50
	Trichlorofluoromethane	OVB-S	ND	ND	2	0	NA	0	520	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Vinyl chloride	OVB-S	ND	ND	3	0	NA	0	2	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Xylene, Total	OVB-S	ND	ND	3	0		0	10000	0	0	0
		OVB / INT	ND	ND	2	0	NA	0		0	0	0

Table 5-7

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**Focus Area 3**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
SEMIVOLATILES	1,2,4-Trichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	70	0	0	0
	1,2-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	600	0	0	0
	1,3-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	NA	0	0	0
	1,4-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	75	0	0	0
	1-Methylnaphthalene	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	1	0	NA	0	1.1	0	0	0
	2,4,5-Trichlorophenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	120	0	0	0
	2,4,6-Trichlorophenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	1.2	0	0	0
	2,4-Dichlorophenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	4.6	0	0	0
	2,4-Dimethylphenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	36	0	0	0
	2,4-Dinitrophenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	3.9	0	0	0
	2,4-Dinitrotoluene	OVB / INT	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	0.11	0	0	0
	2,6-Dinitrotoluene	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	0.11	0	0	0
	2-Chloronaphthalene	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	75	0	0	0
	2-Chlorophenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	9.1	0	0	0
	2-Methylnaphthalene	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	3.6	0	0	0
	2-Methylphenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	93	0	0	0
	2-Nitroaniline	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	19	0	0	0
	2-Nitrophenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	NA	0	0	0
	3,3'-Dichlorobenzidine	OVB-S	ND	ND	1	0		0		0	0	0
		OVB / INT	ND	ND	1	0	NA	0	0.13	0	0	0
	3-Methylphenol and 4-Methylphenol	OVB / INT	ND	ND	1	0		0		0	0	0
		OVB / INT	ND	ND	1	0	NA	0	NA	0	0	0
	3-Nitroaniline	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	NA	0	0	0
	4,6-Dinitro-2-methylphenol	OVB / INT	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	0.15	0	0	0
	4-Bromophenyl phenyl ether	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	NA	0	0	0
	4-Chloro-3-methylphenol	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	140	0	0	0
	4-Chloroaniline	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	0.37	0	0	0
	4-Chlorophenyl phenyl ether	OVB-S	ND	ND	2	0		0		0	0	0
		OVB / INT	ND	ND	2	0	NA	0	NA	0	0	0

Table 5-7

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	4-Methylphenol	OVB-S	ND	ND	2	0	NA	0	190	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	4-Nitroaniline	OVB-S	ND	ND	2	0	NA	0	3.8	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	4-Nitrophenol	OVB-S	ND	ND	2	0	NA	0	NA	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Acenaphthene	OVB-S	ND	ND	2	0	NA	0	53	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Acenaphthylene	OVB-S	ND	ND	2	0	NA	0	47	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Anthracene	OVB-S	ND	ND	2	0	NA	0	180	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Benzo(a)anthracene	OVB-S	ND	ND	2	0	NA	0	0.03	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Benzo(a)pyrene	OVB-S	ND	ND	2	0	NA	0	0.2	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Benzo(b)fluoranthene	OVB-S	ND	ND	2	0	NA	0	0.25	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Benzo(ghi)perylene	OVB-S	ND	ND	2	0	NA	0	60	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Benzo(k)fluoranthene	OVB-S	ND	ND	2	0	NA	0	2.5	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	bis(2-Chloroethoxy)methane	OVB-S	ND	ND	2	0	NA	0	5.9	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	bis(2-Chloroisopropyl)ether	OVB-S	ND	ND	2	0	NA	0	71	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	bis(2-Ethylhexyl)phthalate	OVB-S	ND	ND	2	0	NA	0	6	0	0	0
		OVB / INT	1.3	1.3	2	1		0		0	50	0
	Butyl benzyl phthalate	OVB-S	ND	ND	2	0	NA	0	16	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Carbazole	OVB-S	ND	ND	2	0	NA	0	NA	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Chrysene	OVB-S	ND	ND	2	0	NA	0	25	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Dibenz(a,h)anthracene	OVB / INT	ND	ND	1	0	NA	0	0.025	0	0	0
	Dibenzofuran	OVB-S	ND	ND	2	0	NA	0	0.79	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Diethyl phthalate	OVB-S	ND	ND	2	0	NA	0	1500	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Dimethyl phthalate	OVB-S	ND	ND	2	0	NA	0	NA	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Di-n-butyl phthalate	OVB-S	ND	ND	2	0	NA	0	90	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Di-n-octyl phthalate	OVB-S	ND	ND	2	0	NA	0	20	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Fluoranthene	OVB-S	ND	ND	2	0	NA	0	80	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Fluorene	OVB-S	ND	ND	2	0	NA	0	29	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Hexachlorobenzene	OVB-S	ND	ND	2	0	NA	0	1	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Hexachlorobutadiene	OVB-S	ND	ND	2	0	NA	0	0.14	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Hexachlorocyclopentadiene	OVB-S	ND	ND	2	0	NA	0	50	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Hexachloroethane	OVB-S	ND	ND	2	0	NA	0	0.33	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Indeno(1,2,3-cd)pyrene	OVB-S	ND	ND	2	0	NA	0	0.25	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Isophorone	OVB-S	ND	ND	2	0	NA	0	78	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Naphthalene	OVB-S	ND	ND	2	0	NA	0	0.17	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Nitrobenzene	OVB-S	ND	ND	2	0	NA	0	0.14	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	n-Nitrosodiphenylamine	OVB-S	ND	ND	2	0	NA	0	12	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Pentachlorophenol	OVB-S	ND	ND	2	0	NA	0	1	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Phenanthrene	OVB-S	ND	ND	2	0	NA	0	18	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Phenol	OVB-S	ND	ND	2	0	NA	0	580	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Pyrene	OVB-S	ND	ND	2	0	NA	0	12	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
PESTICIDES/PCBS	4,4'-DDD	OVB-S	ND	ND	2	0	NA	0	0.032	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	4,4'-DDE	OVB-S	ND	ND	2	0	NA	0	0.046	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	4,4'-DDT	OVB-S	ND	ND	2	0	NA	0	0.23	0	0	0
		OVB / INT	ND	ND	2	0		0		0	0	0
	Aldrin	OVB-S	ND	ND	2	0	NA	0	0.00092	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	alpha-BHC	OVB-S	ND	ND	2	0	NA	0	0.0072	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	alpha-Chlordane	OVB-S	ND	ND	2	0	NA	0	2	0	0	0
		OVB / INT	ND	ND	1	0		0		0	0	0
	Aroclor 1016	OVB-S	ND	ND	2	0	NA	0	0.5	0	0	0
	Aroclor 1221	OVB-S	ND	ND	2	0	NA	0	0.5	0	0	0
	Aroclor 1232	OVB-S	ND	ND	2	0	NA	0	0.5	0	0	0
	Aroclor 1242	OVB-S	ND	ND	2	0	NA	0	0.5	0	0	0

Table 5-7

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 3**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Aroclor 1248	OVB-S	ND	ND	2	0	NA	0	0.5	0	0	0
	Aroclor 1254	OVB-S	ND	ND	2	0	NA	0	0.5	0	0	0
	Aroclor 1260	OVB-S	ND	ND	2	0	NA	0	0.5	0	0	0
	beta-BHC	OVB-S	ND	ND	2	0	NA	0	0.025	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	delta-BHC	OVB-S	ND	ND	2	0	NA	0	0.36	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Dieldrin	OVB-S	ND	ND	2	0	NA	0	0.0018	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Endosulfan I	OVB-S	ND	ND	2	0	NA	0	10	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Endosulfan II	OVB-S	ND	ND	2	0	NA	0	10	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Endosulfan sulfate	OVB-S	ND	ND	2	0	NA	0	10	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Endrin	OVB-S	ND	ND	2	0	NA	0	2	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Endrin aldehyde	OVB-S	ND	ND	2	0	NA	0	0.23	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Endrin ketone	OVB-S	ND	ND	2	0	NA	0	0.23	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	gamma-BHC (Lindane)	OVB-S	ND	ND	2	0	NA	0	0.2	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	gamma-Chlordane	OVB-S	ND	ND	2	0	NA	0	2	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Heptachlor	OVB-S	ND	ND	2	0	NA	0	0.4	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Heptachlor epoxide	OVB-S	ND	ND	2	0	NA	0	0.2	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Methoxychlor	OVB-S	ND	ND	2	0	NA	0	40	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
	Toxaphene	OVB-S	ND	ND	2	0	NA	0	3	0	0	0
		OVB / INT	ND	ND	1	0	NA	0		0	0	0
PERCHLORATE	Perchlorate	OVB / INT	ND	ND	1	1	NA	0	15	0	100	0
METALS	Aluminum	OVB-S	154	1200	2	2	9434	0	2000	0	100	0
	Antimony	OVB-S	ND	ND	2	0	17	0	6	0	0	0
	Arsenic	OVB-S	ND	ND	2	0	5.1	0	10	0	0	0
	Barium	OVB-S	10.3	15.8	2	2	156	0	2000	0	100	0
	Beryllium	OVB-S	ND	ND	2	0	5	0	4	0	0	0
	Cadmium	OVB-S	ND	ND	2	0	5	0	5	0	0	0
	Calcium	OVB-S	2200	5490	2	2	144000	0	NA	0	100	0
	Chromium	OVB-S	5.16	5.16	2	1	16	0	100	0	50	0
	Cobalt	OVB-S	ND	ND	2	0	50	0	0.6	0	0	0
	Copper	OVB-S	24.1	24.1	2	1	25	0	1300	0	50	0



Table 5-7

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 3**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Iron	OVB-S	180	1400	2	2	12100	0	1400	0	100	0
	Lead	OVB-S	3.85	3.85	2	1	5.2	0	15	0	50	0
	Magnesium	OVB-S	1290	1290	2	1	19414	0	NA	0	50	0
	Manganese	OVB-S	8.78	14	2	2	3220	0	43	0	100	0
	Mercury	OVB-S	0.08	0.08	2	1	0.2	0	2	0	50	0
	Nickel	OVB-S	3.74	3.74	2	1	40	0	100	0	50	0
	Potassium	OVB-S	ND	ND	2	0	5810	0	NA	0	0	0
	Selenium	OVB-S	ND	ND	2	0	5	0	50	0	0	0
	Silver	OVB-S	ND	ND	2	0	10	0	9.4	0	0	0
	Sodium	OVB-S	2810	3150	2	2	65600	0	NA	0	100	0
	Thallium	OVB-S	ND	ND	2	0	5.7	0	2	0	0	0
	Vanadium	OVB-S	ND	ND	2	0	50	0	8.6	0	0	0
	Zinc	OVB-S	5.29	19.8	2	2	211	0	600	0	100	0

µg/L - Micrograms per liter.

BSV - Background screening value.

MR - Most recent.

PSV - Preliminary screening value.

UTG - User test group.

<sup>(1)</sup> The Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:

- 1) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).
- 2) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017 *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, June, <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017>). The health advisory level is used for perchlorate (DoD, 2009, *Perchlorate Release Management Policy*, Memorandum from Wayne Army to Deputy Assistant Secretaries of the Army, Navy, and Air Force, 4 April).

<sup>(2)</sup> Ratio of detected concentrations in usable samples to the total number of samples collected.<sup>(3)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of usable samples analyzed.

**Table 5-8**

**Analytical Summary, Deep Flow Zone Locations, Focus Area 3**

**RSA-147/148/149**

**Redstone Arsenal, Madison County, Alabama**

					<b>Most Recent Sample Results</b>	
<b>Location Code</b>	<b>Depth, Bottom of Screened Interval (ft bgs)</b>	<b>User Test Group</b>	<b>Parameter</b>	<b>PSV</b>	<b>Result</b>	<b>VQ</b>
147-RS1968	247	VOCs	Carbon tetrachloride	5	20	U
			Trichloroethene	5	20	U
147-RS2249D	282	VOCs	Carbon tetrachloride	5	20	U
			Trichloroethene	5	20	U
147-RS2250D	310	VOCs	Carbon tetrachloride	5	200	U
147-RS2250S	180	VOCs	Carbon tetrachloride	5	200	U
F122-RS513	126.4	VOCs	1,1,2,2-Tetrachloroethane	0.076	1	UJ
			Carbon tetrachloride	5	1	UJ
			Trichloroethene	5	1	UJ
F53-RS354	199.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	1	U
			Carbon tetrachloride	5	1	U
			Trichloroethene	5	1	U
F55-RS1063	161.75	VOCs	1,1,2,2-Tetrachloroethane	0.076	1	U
			Carbon tetrachloride	5	1	U
			Trichloroethene	5	1.6	
Z-RS1232D	150	VOCs	1,1,2,2-Tetrachloroethane	0.076	1	U
			Carbon tetrachloride	5	1	U
			Trichloroethene	5	81	
Z-RS1236D	147	VOCs	1,1,2,2-Tetrachloroethane	0.076	1	U
			Carbon tetrachloride	5	1	U
			Trichloroethene	5	1	U

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
VOLATILES	1,1,1-Trichloroethane	Spring	ND	ND	1	0	NA	0	200	0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
		OV-B / INT	ND	ND	12	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	1,1,2,2-Tetrachloroethane	Spring	ND	ND	1	0	NA	0	0.076	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	1	1	5	1		0		1	20	20
		BR	8.99	8.99	4	1		0		1	25	25
		BR-D	ND	ND	2	0		0		0	0	0
	1,1,2-Trichloroethane	Spring	ND	ND	1	0	NA	0	5	0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
		OV-B / INT	ND	ND	11	0		0		0	0	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	1,1-Dichloroethane	Spring	0.26	0.26	1	1	NA	0	2.8	0	100	0
		OV-B-S	0.5	37.3	6	4		0		2	67	33
		OV-B / INT	0.508	0.69	11	2		0		0	18	0
		BR	0.57	0.57	6	1		0		0	17	0
		BR-D	ND	ND	2	0		0		0	0	0
	1,1-Dichloroethene	Spring	ND	ND	1	0	NA	0	7	0	0	0
		OV-B-S	0.47	0.47	6	1		0		0	17	0
		OV-B / INT	ND	ND	11	0		0		0	0	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	1,2,4-Trichlorobenzene	Spring	ND	ND	1	0	NA	0	70	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	ND	ND	10	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,2-Dichlorobenzene	Spring	ND	ND	1	0	NA	0	600	0	0	0
		OV-B-S	6.7	6.7	5	1		0		0	20	0
		OV-B / INT	ND	ND	8	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,2-Dichloroethane	Spring	ND	ND	1	0	NA	0	5	0	0	0
		OV-B-S	0.834	0.834	6	1		0		0	17	0
		OV-B / INT	0.53	1.8	11	2		0		0	18	0
		BR	1.5	1.5	6	1		0		0	17	0
		BR-D	ND	ND	2	0		0		0	0	0
	1,2-Dichloroethene	BR	1.9	1.9	1	1	NA	0	NA	0	100	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	1,2-Dichloropropane	Spring	ND	ND	1	0	NA	0	5	0	0	0
		OVBS	0.801	0.801	6	1		0		0	17	0
		OVBS / INT	ND	ND	11	0		0		0	0	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	1,3-Dichlorobenzene	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	ND	ND	10	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,4-Dichlorobenzene	Spring	ND	ND	1	0	NA	0	75	0	0	0
		OVBS	1.39	9.1	5	3		0		0	60	0
		OVBS / INT	2.1	34	10	2		0		0	20	0
		BR	1.1	6.5	7	2		0		0	29	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Butanone	Spring	ND	ND	1	0	NA	0	560	0	0	0
		OVBS	ND	ND	6	0		0		0	0	0
		OVBS / INT	408	408	12	1		0		0	8.3	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	2-Hexanone	Spring	ND	ND	1	0	NA	0	3.8	0	0	0
		OVBS	ND	ND	6	0		0		0	0	0
		OVBS / INT	ND	ND	8	0		0		0	0	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	4-Methyl-2-pentanone	Spring	ND	ND	1	0	NA	0	630	0	0	0
		OVBS	ND	ND	6	0		0		0	0	0
		OVBS / INT	ND	ND	12	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Acetone	Spring	ND	ND	1	0	NA	0	1400	0	0	0
		OVBS	ND	ND	6	0		0		0	0	0
		OVBS / INT	229	2410	12	3		0		1	25	8.3
		BR	193	193	7	1		0		0	14	0
		BR-D	ND	ND	2	0		0		0	0	0
	Benzene	Spring	ND	ND	1	0	NA	0	5	0	0	0
		OVBS	0.26	2.95	6	4		0		0	67	0
		OVBS / INT	1.3	187	11	3		0		2	27	18
		BR	0.99	103	7	3		0		2	43	29
		BR-D	ND	ND	2	0		0		0	0	0
	Bromochloromethane	OVBS	ND	ND	2	0	NA	0	8.3	0	0	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Bromodichloromethane	Spring	ND	ND	1	0	NA	0	80	0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
		OV-B / INT	ND	ND	12	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Bromoform	Spring	ND	ND	1	0	NA	0	80	0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
		OV-B / INT	ND	ND	12	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Bromomethane	Spring	ND	ND	1	0	NA	0	0.75	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	ND	ND	6	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Carbon disulfide	Spring	ND	ND	1	0	NA	0	81	0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
		OV-B / INT	30.6	30.6	12	1		0		0	8.3	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Carbon tetrachloride	Spring	ND	ND	1	0	NA	0	5	0	0	0
		OV-B-S	ND	ND	4	0		0		0	0	0
		OV-B / INT	4	4	11	1		0		0	9.1	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Chlorobenzene	Spring	ND	ND	1	0	NA	0	100	0	0	0
		OV-B-S	3.67	42	5	4		0		0	80	0
		OV-B / INT	2.7	50300	10	8		0		7	80	70
		BR	350	12000	6	4		0		4	67	67
		BR-D	1.8	1.8	2	1		0		0	50	0
	Chloroethane	Spring	1.76	1.76	1	1	NA	0	2100	0	100	0
		OV-B-S	2.9	7.71	5	2		0		0	40	0
		OV-B / INT	ND	ND	10	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Chloroform	Spring	ND	ND	1	0	NA	0	80	0	0	0
		OV-B-S	0.34	0.6	5	2		0		0	40	0
		OV-B / INT	0.26	4010	12	11		0		6	92	50
		BR	1.27	225	6	2		0		1	33	17
		BR-D	ND	ND	2	0		0		0	0	0
	Chloromethane	Spring	ND	ND	1	0	NA	0	19	0	0	0
		OV-B-S	ND	ND	6	0		0		0	0	0
		OV-B / INT	ND	ND	11	0		0		0	0	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	cis-1,2-Dichloroethene	Spring	ND	ND	1	0	NA	0	70	0	0	0
		OVBS	0.23	34.5	6	4		0		0	67	0
		OVBS / INT	0.39	1.1	12	2		0		0	17	0
		BR	1.2	1.2	7	1		0		0	14	0
		BR-D	ND	ND	2	0		0		0	0	0
	cis-1,3-Dichloropropene	Spring	ND	ND	1	0	NA	0	0.47	0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	ND	ND	6	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Dibromochloromethane	Spring	ND	ND	1	0	NA	0	80	0	0	0
		OVBS	ND	ND	6	0		0		0	0	0
		OVBS / INT	ND	ND	12	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Dichlorodifluoromethane	Spring	ND	ND	1	0	NA	0	20	0	0	0
		OVBS	ND	ND	4	0		0		0	0	0
		OVBS / INT	0.48	0.48	9	1		0		0	11	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Ethyl methacrylate	OVBS	ND	ND	2	0	NA	0	63	0	0	0
		Spring	ND	ND	1	0		0		0	0	0
		OVBS	ND	ND	6	0		0		0	0	0
	Ethylbenzene	OVBS / INT	ND	ND	12	0	NA	0	700	0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Freon 113	Spring	ND	ND	1	0	NA	0	1000	0	0	0
		OVBS	ND	ND	4	0		0		0	0	0
		OVBS / INT	0.74	0.74	10	1		0		0	10	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Methyl tert-butyl ether	Spring	ND	ND	1	0	NA	0	14	0	0	0
		OVBS	0.6	1.24	4	2		0		0	50	0
		OVBS / INT	ND	ND	9	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Methylene chloride	Spring	ND	ND	1	0	NA	0	5	0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	43.5	6160	10	5		0		5	50	50
		BR	290	1100	4	2		0		2	50	50
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Methylene methacrylate	OV-B-S	ND	ND	2	0	NA	0	140	0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	Styrene	OV-B-S	ND	ND	6	0	NA	0	100	0	0	0
		OV-B / INT	ND	ND	12	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	Tetrachloroethene	OV-B-S	ND	ND	6	0	NA	0	5	0	0	0
		OV-B / INT	0.71	1.3	11	2		0		0	18	0
		BR	0.29	0.29	6	1		0		0	17	0
		BR-D	ND	ND	2	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	Toluene	OV-B-S	ND	ND	6	0	NA	0	1000	0	0	0
		OV-B / INT	0.23	0.23	12	1		0		0	8.3	0
		BR	0.44	0.44	7	1		0		0	14	0
		BR-D	ND	ND	2	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	trans-1,2-Dichloroethene	OV-B-S	ND	ND	6	0	NA	0	100	0	0	0
		OV-B / INT	0.31	0.31	12	1		0		0	8.3	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	trans-1,3-Dichloropropene	OV-B-S	ND	ND	5	0	NA	0	0.47	0	0	0
		OV-B / INT	ND	ND	6	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	Trichloroethene	OV-B-S	0.45	3.15	6	5	NA	0	5	0	83	0
		OV-B / INT	2.2	752	11	5		0		4	45	36
		BR	7.23	7.23	6	1		0		1	17	17
		BR-D	ND	ND	2	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Trichlorofluoromethane	Spring	ND	ND	1	0	NA	0	520	0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	0.67	0.67	10	1		0		0	10	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Vinyl chloride	Spring	ND	ND	1	0	NA	0	2	0	0	0
		OVBS	0.605	3.42	6	3		0		1	50	17
		OVBS / INT	0.86	0.86	9	1		0		0	11	0
		BR	0.97	0.97	6	1		0		0	17	0
		BR-D	ND	ND	2	0		0		0	0	0
	Xylene, Total	Spring	ND	ND	1	0	NA	0	10000	0	0	0
		OVBS	ND	ND	6	0		0		0	0	0
		OVBS / INT	ND	ND	12	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
SEMIVOLATILES	1,2-Dichlorobenzene	OVBS / INT	ND	ND	2	0	NA	0	600	0	0	0
		Spring	ND	ND	1	0		0		0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
	1-Methylnaphthalene	OVBS / INT	ND	ND	3	0	NA	0	1.1	0	0	0
		BR	ND	ND	1	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	2,4,5-Trichlorophenol	OVBS	ND	ND	3	0	NA	0	120	0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	2,4,6-Trichlorophenol	Spring	ND	ND	1	0	NA	0	1.2	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
	2,4-Dichlorophenol	BR	ND	ND	1	0	NA	0	4.6	0	0	0
		Spring	ND	ND	1	0		0		0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
	2,4-Dimethylphenol	OVBS / INT	ND	ND	3	0	NA	0	36	0	0	0
		BR	ND	ND	1	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	2,4-Dinitrophenol	OVBS	ND	ND	3	0	NA	0	3.9	0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0



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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	2-Chloronaphthalene	Spring	ND	ND	1	0	NA	0	75	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	2-Chlorophenol	Spring	ND	ND	1	0	NA	0	9.1	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	2-Methylnaphthalene	Spring	ND	ND	1	0	NA	0	3.6	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	2-Methylphenol	Spring	ND	ND	1	0	NA	0	93	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	2-Nitroaniline	Spring	ND	ND	1	0	NA	0	19	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	2-Nitrophenol	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	3,3'-Dichlorobenzidine	Spring	ND	ND	1	0	NA	0	0.13	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	3-Nitroaniline	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	4-Bromophenyl phenyl ether	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	4-Chloro-3-methylphenol	Spring	ND	ND	1	0	NA	0	140	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	4-Chloroaniline	Spring	ND	ND	1	0	NA	0	0.37	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	4-Chlorophenyl phenyl ether	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	4-Methylphenol	Spring	ND	ND	1	0	NA	0	190	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	4-Nitroaniline	Spring	ND	ND	1	0	NA	0	3.8	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	4-Nitrophenol	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Acenaphthene	Spring	ND	ND	1	0	NA	0	53	0	0	0
		OVB-S	0.0593	0.09	3	2		0		0	67	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Acenaphthylene	Spring	ND	ND	1	0	NA	0	47	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Anthracene	Spring	ND	ND	1	0	NA	0	180	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Benzo(a)anthracene	Spring	ND	ND	1	0	NA	0	0.03	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Benzo(a)pyrene	Spring	ND	ND	1	0	NA	0	0.2	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Benzo(b)fluoranthene	Spring	ND	ND	1	0	NA	0	0.25	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Benzo(ghi)perylene	Spring	ND	ND	1	0	NA	0	60	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Benzo(k)fluoranthene	Spring	ND	ND	1	0	NA	0	2.5	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	bis(2-Chloroethoxy)methane	Spring	ND	ND	1	0	NA	0	5.9	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	bis(2-Chloroisopropyl)ether	Spring	ND	ND	1	0	NA	0	71	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	bis(2-Ethylhexyl)phthalate	Spring	ND	ND	1	0	NA	0	6	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	0.51	14	3	3		0		1	100	33
		BR	ND	ND	1	0		0		0	0	0
	Butyl benzyl phthalate	Spring	ND	ND	1	0	NA	0	16	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Carbazole	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Chrysene	Spring	ND	ND	1	0	NA	0	25	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Dibenz(a,h)anthracene	OVBS	ND	ND	1	0	NA	0	-0.025	0	0	0
		OVBS / INT	ND	ND	1	0		0		0	0	0
	Dibenzofuran	Spring	ND	ND	1	0	NA	0	0.79	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Diethyl phthalate	Spring	ND	ND	1	0	NA	0	1500	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Dimethyl phthalate	Spring	ND	ND	1	0	NA	0	NA	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Di-n-butyl phthalate	Spring	ND	ND	1	0	NA	0	90	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	0.47	0.47	3	1		0		0	33	0
		BR	ND	ND	1	0		0		0	0	0
	Di-n-octyl phthalate	Spring	ND	ND	1	0	NA	0	20	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Fluoranthene	Spring	ND	ND	1	0	NA	0	80	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Fluorene	Spring	ND	ND	1	0	NA	0	29	0	0	0
		OVB-S	0.06	0.06	3	1		0		0	33	0
		OVB / INT	0.06	0.06	3	1		0		0	33	0
		BR	ND	ND	1	0		0		0	0	0
	Hexachlorobenzene	Spring	ND	ND	1	0	NA	0	1	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Hexachlorobutadiene	Spring	ND	ND	1	0	NA	0	0.14	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Hexachlorocyclopentadiene	Spring	ND	ND	1	0	NA	0	50	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Hexachloroethane	Spring	ND	ND	1	0	NA	0	0.33	0	0	0
		OVB-S	ND	ND	3	0		0		0	0	0
		OVB / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0

Table 5-9

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Indeno(1,2,3-cd)pyrene	Spring	ND	ND	1	0	NA	0	0.25	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Isophorone	Spring	ND	ND	1	0	NA	0	78	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Naphthalene	Spring	ND	ND	1	0	NA	0	0.17	0	0	0
		OV-B-S	0.0541	0.0541	3	1		0		0	33	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Nitrobenzene	Spring	ND	ND	1	0	NA	0	0.14	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	0.1	0.13	1	0		0		0	0	0
	n-Nitrosodiphenylamine	Spring	ND	ND	1	0	NA	0	12	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Pentachlorophenol	Spring	ND	ND	1	0	NA	0	1	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Phenanthrene	Spring	ND	ND	1	0	NA	0	18	0	0	0
		OV-B-S	0.05	0.05	3	1		0		0	33	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Phenol	Spring	ND	ND	1	0	NA	0	580	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Pyrene	Spring	ND	ND	1	0	NA	0	12	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
PESTICIDES/PCBS	4,4'-DDD	Spring	ND	ND	1	0	NA	0	0.032	0	0	0
		OVBS	0.01	0.01	5	1		0		0	20	0
		OVBS / INT	0.535	0.535	7	1		0		1	14	14
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	4,4'-DDE	Spring	ND	ND	1	0	NA	0	0.046	0	0	0
		OVBS	0.01	0.02	5	2		0		0	40	0
		OVBS / INT	0.0013	0.524	7	2		0		1	29	14
		BR	0.0889	0.0889	6	1		0		1	17	17
		BR-D	ND	ND	2	0		0		0	0	0
	4,4'-DDT	Spring	ND	ND	1	0	NA	0	0.23	0	0	0
		OVBS	0.03	0.03	5	1		0		0	20	0
		OVBS / INT	0.0201	0.16	7	3		0		0	43	0
		BR	0.00108	0.17	6	2		0		0	33	0
		BR-D	ND	ND	2	0		0		0	0	0
	Aldrin	Spring	ND	ND	1	0	NA	0	0.00092	0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	ND	ND	7	0		0		0	0	0
		BR	0.05	0.05	7	1		0		1	14	14
		BR-D	ND	ND	2	0		0		0	0	0
	alpha-BHC	Spring	ND	ND	1	0	NA	0	0.0072	0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	0.0034	0.0542	6	2		0		1	33	17
		BR	0.00264	0.00264	5	1		0		0	20	0
		BR-D	ND	ND	2	0		0		0	0	0
	alpha-Chlordane	Spring	ND	ND	1	0	NA	0	2	0	0	0
		OVBS	0.02	0.02	5	1		0		0	20	0
		OVBS / INT	0.0358	0.65	7	2		0		0	29	0
		BR	0.07	0.51	7	3		0		0	43	0
		BR-D	ND	ND	2	0		0		0	0	0
	Aroclor 1016	Spring	ND	ND	1	0	NA	0	0.5	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Aroclor 1221	Spring	ND	ND	1	0	NA	0	0.5	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Aroclor 1232	Spring	ND	ND	1	0	NA	0	0.5	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Aroclor 1242	Spring	ND	ND	1	0		0	0.5	0	0	0
		OV-B-S	ND	ND	3	0	NA	0		0	0	0
	Aroclor 1248	BR	ND	ND	1	0		0	0.5	0	0	0
		Spring	ND	ND	1	0		0		0	0	0
		OV-B-S	ND	ND	3	0	NA	0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Aroclor 1254	Spring	ND	ND	1	0		0	0.5	0	0	0
		OV-B-S	ND	ND	3	0	NA	0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Aroclor 1260	Spring	ND	ND	1	0		0	0.5	0	0	0
		OV-B-S	ND	ND	3	0	NA	0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
	beta-BHC	Spring	ND	ND	1	0		0	0.025	0	0	0
		OV-B-S	0.01	0.03	5	2		0		1	40	20
		OV-B / INT	0.03	0.0309	7	2	NA	0		2	29	29
		BR	0.00447	0.0379	6	6		0		3	100	50
		BR-D	ND	ND	2	0		0		0	0	0
	delta-BHC	Spring	0.02	0.02	1	1		0	0.36	0	100	0
		OV-B-S	0.0055	0.0055	5	1		0		0	20	0
		OV-B / INT	0.0086	0.0086	7	1	NA	0		0	14	0
		BR	0.00352	0.15	7	4		0		0	57	0
		BR-D	ND	ND	2	0		0		0	0	0
	Dieldrin	Spring	ND	ND	1	0		0	0.0018	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	0.0243	0.0243	7	1	NA	0		1	14	14
		BR	0.03	0.03	7	1		0		1	14	14
		BR-D	ND	ND	2	0		0		0	0	0
	Endosulfan I	Spring	ND	ND	1	0		0	10	0	0	0
		OV-B-S	0.00373	0.63	5	3		0		0	60	0
		OV-B / INT	0.0074	0.06	7	4	NA	0		0	57	0
		BR	0.00167	0.13	7	3		0		0	43	0
		BR-D	ND	ND	2	0		0		0	0	0
	Endosulfan II	Spring	ND	ND	1	0		0	10	0	0	0
		OV-B-S	0.00868	0.03	5	2		0		0	40	0
		OV-B / INT	ND	ND	7	0	NA	0		0	0	0
		BR	0.1	1.13	7	2		0		0	29	0
		BR-D	ND	ND	2	0		0		0	0	0
	Endosulfan sulfate	Spring	ND	ND	1	0		0	10	0	0	0
		OV-B-S	0.00707	0.07	5	3		0		0	60	0
		OV-B / INT	0.0499	0.05	7	2	NA	0		0	29	0
		BR	0.04	0.37	7	2		0		0	29	0
		BR-D	ND	ND	2	0		0		0	0	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Endrin	Spring	0.00976	0.00976	1	1	NA	0	2	0	100	0
		OV-B-S	0.00622	0.11	5	3		0		0	60	0
		OV-B / INT	0.00953	0.00953	7	1		0		0	14	0
		BR	0.01	0.01	7	1		0		0	14	0
		BR-D	ND	ND	2	0		0		0	0	0
	Endrin aldehyde	Spring	ND	ND	1	0	NA	0	0.23	0	0	0
		OV-B-S	0.04	0.04	5	1		0		0	20	0
		OV-B / INT	0.05	0.05	7	1		0		0	14	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	Endrin ketone	Spring	ND	ND	1	0	NA	0	0.23	0	0	0
		OV-B-S	0.05	0.05	5	1		0		0	20	0
		OV-B / INT	0.01	0.01	7	1		0		0	14	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	gamma-BHC (Lindane)	Spring	ND	ND	1	0	NA	0	0.2	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	0.0039	0.141	7	3		0		0	43	0
		BR	0.01	0.07	7	2		0		0	29	0
		BR-D	ND	ND	2	0		0		0	0	0
	gamma-Chlordane	Spring	0.01	0.01	1	1	NA	0	2	0	100	0
		OV-B-S	0.01	0.18	5	2		0		0	40	0
		OV-B / INT	0.15	0.168	7	2		0		0	29	0
		BR	0.00127	0.12	7	2		0		0	29	0
		BR-D	ND	ND	2	0		0		0	0	0
	Heptachlor	Spring	0.00896	0.00896	1	1	NA	0	0.4	0	100	0
		OV-B-S	0.00625	0.08	5	4		0		0	80	0
		OV-B / INT	0.0221	0.22	7	2		0		0	29	0
		BR	0.00385	0.21	7	3		0		0	43	0
		BR-D	ND	ND	2	0		0		0	0	0
	Heptachlor epoxide	Spring	0.02	0.02	1	1	NA	0	0.2	0	100	0
		OV-B-S	0.01	0.01	5	2		0		0	40	0
		OV-B / INT	0.01	0.0402	7	2		0		0	29	0
		BR	0.02	0.02	6	1		0		0	17	0
		BR-D	ND	ND	2	0		0		0	0	0
	Methoxychlor	Spring	ND	ND	1	0	NA	0	40	0	0	0
		OV-B-S	0.01	0.19	5	2		0		0	40	0
		OV-B / INT	0.0801	0.39	7	2		0		0	29	0
		BR	0.17	0.4	7	2		0		0	29	0
		BR-D	ND	ND	2	0		0		0	0	0



Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
EXPLOSIVES	Toxaphene	Spring	ND	ND	1	0	NA	0	3	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	ND	ND	7	0		0		0	0	0
		BR	ND	ND	7	0		0		0	0	0
		BR-D	ND	ND	2	0		0		0	0	0
	1,3,5-Trinitrobenzene	Spring	ND	ND	1	0	NA	0	59	0	0	0
		OV-B-S	ND	ND	4	0		0		0	0	0
		OV-B / INT	ND	ND	6	0		0		0	0	0
		BR	2.12	8.05	6	2		0		0	33	0
		BR-D	ND	ND	1	0		0		0	0	0
	1,3-Dinitrobenzene	Spring	ND	ND	1	0	NA	0	0.2	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		OV-B / INT	ND	ND	5	0		0		0	0	0
		BR	11.3	11.3	5	1		0		1	20	20
		BR-D	ND	ND	1	0		0		0	0	0
	2,4,6-Trinitrotoluene	Spring	ND	ND	1	0	NA	0	0.98	0	0	0
		OV-B-S	ND	ND	4	0		0		0	0	0
		OV-B / INT	ND	ND	6	0		0		0	0	0
		BR	2.24	2.24	6	1		0		1	17	17
		BR-D	ND	ND	1	0		0		0	0	0
	2,4-Dinitrotoluene	Spring	ND	ND	1	0	NA	0	0.11	0	0	0
		OV-B-S	0.11	0.11	3	1		0		0	33	0
		OV-B / INT	ND	ND	5	0		0		0	0	0
		BR	11.4	36.7	6	2		0		2	33	33
		BR-D	ND	ND	1	0		0		0	0	0

Table 5-9

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 4

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	2,6-Dinitrotoluene	Spring	ND	ND	1	0	NA	0	0.11	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	6	0		0		0	0	0
		BR	ND	ND	5	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	2-Amino-4,6-dinitrotoluene	Spring	ND	ND	1	0	NA	0	3.9	0	0	0
		OVBS	0.25	0.26	3	2		0		0	67	0
		OVBS / INT	ND	ND	6	0		0		0	0	0
		BR	43.4	269	6	2		0		2	33	33
		BR-D	ND	ND	1	0		0		0	0	0
	2-Nitrotoluene	Spring	ND	ND	1	0	NA	0	0.31	0	0	0
		OVBS	13.4	14.6	3	2		0		2	67	67
		OVBS / INT	ND	ND	5	0		0		0	0	0
		BR	1	1.13	5	2		0		2	40	40
		BR-D	ND	ND	1	0		0		0	0	0
	3-Nitrotoluene	Spring	ND	ND	1	0	NA	0	0.17	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	5	0		0		0	0	0
		BR	1.04	1.04	6	1		0		1	17	17
		BR-D	ND	ND	1	0		0		0	0	0
	4-Amino-2,6-dinitrotoluene	Spring	ND	ND	1	0	NA	0	3.9	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	5	0		0		0	0	0
		BR	0.26	72.9	5	4		0		2	80	40
		BR-D	ND	ND	1	0		0		0	0	0
	HMX	Spring	ND	ND	1	0	NA	0	100	0	0	0
		OVBS	ND	ND	4	0		0		0	0	0
		OVBS / INT	ND	ND	6	0		0		0	0	0
		BR	1	1	6	1		0		0	17	0
		BR-D	ND	ND	1	0		0		0	0	0
	Nitrobenzene	Spring	ND	ND	1	0	NA	0	0.14	0	0	0
		OVBS	ND	ND	4	0		0		0	0	0
		OVBS / INT	ND	ND	6	0		0		0	0	0
		BR	0.1	0.13	4	2		0		0	50	0
		BR-D	ND	ND	1	0		0		0	0	0
	Nitroglycerin	Spring	ND	ND	1	0	NA	0	0.2	0	0	0
		OVBS	ND	ND	3	0		0		0	0	0
		OVBS / INT	ND	ND	3	0		0		0	0	0
		BR	48.3	48.3	4	1		0		1	25	25

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	PETN	Spring	ND	ND	1	0	NA	0	3.9	0	0	0
		OV-B-S	2.8	2.8	4	1		0		0	25	0
		OV-B / INT	ND	ND	4	0		0		0	0	0
		BR	0.289	5.02	5	3		0		1	60	20
	p-Nitrotoluene	Spring	ND	ND	1	0	NA	0	4.3	0	0	0
		OV-B-S	0.22	2.64	4	2		0		0	50	0
		OV-B / INT	2.77	2.77	6	1		0		0	17	0
		BR	0.7	0.7	5	1		0		0	20	0
		BR-D	ND	ND	1	0		0		0	0	0
		Spring	ND	ND	1	0		0		0	0	0
	RDX	OV-B-S	0.24	0.24	4	1	NA	0	0.7	0	25	0
		OV-B / INT	ND	ND	5	0		0		0	0	0
		BR	0.897	106	6	2		0		2	33	33
		BR-D	ND	ND	1	0		0		0	0	0
	Tetryl	Spring	ND	ND	1	0	NA	0	3.9	0	0	0
		OV-B-S	0.16	0.52	4	2		0		0	50	0
		OV-B / INT	0.13	0.13	6	1		0		0	17	0
		BR	ND	ND	6	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
PERCHLORATE	Perchlorate	Spring	ND	ND	1	0	NA	0	15	0	0	0
		OV-B-S	ND	ND	3	0		0		0	0	0
		BR	ND	ND	1	0		0		0	0	0
METALS	Aluminum	Spring	55.6	55.6	1	1	9434	0	2000	0	100	0
		OV-B-S	57.2	567	5	4		0		0	80	0
		OV-B / INT	52	547	2	2		0		0	100	0
		BR	5.9	113	4	2		0		0	50	0
		BR-D	200	200	1	1		0		0	100	0
	Antimony	Spring	ND	ND	1	0	17	0	6	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	ND	ND	2	0		0		0	0	0
		BR	ND	ND	4	0		0		0	0	0
		BR-D	1.5	1.5	1	1		0		0	100	0
	Arsenic	Spring	ND	ND	1	0	5.1	0	10	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	1.7	1.7	2	1		0		0	50	0
		BR	1	9.5	4	3		1		0	75	0
	Barium	Spring	56.9	56.9	1	1	156	0	2000	0	100	0
		OV-B-S	6.03	71.9	5	5		0		0	100	0
		OV-B / INT	24.2	69	2	2		0		0	100	0
		BR	17.9	283	4	4		1		0	100	0
		BR-D	83	83	1	1		0		0	100	0

Table 5-9

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 4

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Beryllium	Spring	ND	ND	1	0	5	0	4	0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	1.51	1.51	2	1		0		0	50	0
		BR	ND	ND	4	0		0		0	0	0
	Cadmium	Spring	ND	ND	1	0	5	0	5	0	0	0
		OVBS	1	1	5	1		0		0	20	0
		OVBS / INT	2.04	2.04	2	1		0		0	50	0
		BR	ND	ND	4	0		0		0	0	0
	Calcium	Spring	33600	33600	1	1	144000	0	NA	0	100	0
		OVBS	1110	116000	5	5		0		0	100	0
		OVBS / INT	14400	49000	2	2		0		0	100	0
		BR	64600	130000	4	4		0		0	100	0
	Chromium	BR-D	29000	29000	1	1	16	0	100	0	100	0
		Spring	ND	ND	1	0		0		0	0	0
		OVBS	2	2.45	5	2		0		0	40	0
		OVBS / INT	0.9	0.9	2	1		0		0	50	0
	Cobalt	BR	ND	ND	4	0	50	0	0.6	0	0	0
		BR-D	0.48	0.48	1	1		0		0	100	0
		Spring	ND	ND	1	0		0		0	0	0
		OVBS	12.3	12.3	5	1		0		1	20	0
	Copper	OVBS / INT	0.36	0.36	2	1	25	0	1300	0	50	0
		BR	1.3	6.7	4	2		0		2	50	0
		Spring	ND	ND	1	0		0		0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
	Iron	OVBS / INT	1.6	1.6	2	1	12100	0	1400	0	50	0
		BR	0.34	0.34	4	1		0		0	25	0
		BR-D	1.5	1.5	1	1		0		0	100	0
		Spring	ND	ND	1	0		0		0	0	0
	Lead	OVBS	41.7	8710	5	4	5.2	0	15	1	80	0
		OVBS / INT	113	370	2	2		0		0	100	0
		BR	55.2	6700	4	4		0		3	100	0
		Spring	ND	ND	1	0		0		0	0	0
		OVBS	ND	ND	5	0		0		0	0	0
		OVBS / INT	0.32	0.32	2	1		0		0	50	0
		BR	ND	ND	4	0		0		0	0	0
		BR-D	1.2	1.2	1	1		0		0	100	0

Table 5-9

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 4

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

(Page 19 of 20)

UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Magnesium	Spring	9190	9190	1	1	19414	0	NA	0	100	0
		OV-B-S	2960	10300	5	4		0		0	80	0
		OV-B / INT	2820	4800	2	2		0		0	100	0
		BR	4460	38800	4	4		2		0	100	0
		BR-D	1100	1100	1	1		0		0	100	0
	Manganese	Spring	86.1	86.1	1	1	3220	0	43	1	100	0
		OV-B-S	16.9	852	5	5		0		4	100	0
		OV-B / INT	160	245	2	2		0		2	100	0
		BR	4.16	5700	4	4		1		3	100	25
		BR-D	ND	ND	1	0		0		0	0	0
	Mercury	Spring	ND	ND	1	0	0.2	0	2	0	0	0
		OV-B-S	0.315	0.315	5	1		1		0	20	0
		OV-B / INT	ND	ND	2	0		0		0	0	0
		BR	ND	ND	4	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Nickel	Spring	ND	ND	1	0	40	0	100	0	0	0
		OV-B-S	8.6	8.6	5	1		0		0	20	0
		OV-B / INT	2	36.7	2	2		0		0	100	0
		BR	5.9	17.9	4	3		0		0	75	0
		BR-D	2.2	2.2	1	1		0		0	100	0
	Potassium	Spring	2110	2110	1	1	5810	0	NA	0	100	0
		OV-B-S	1170	2200	5	3		0		0	60	0
		OV-B / INT	4900	4900	2	1		0		0	50	0
		BR	1100	8830	4	3		1		0	75	0
		BR-D	ND	ND	1	0		0		0	0	0
	Selenium	Spring	ND	ND	1	0	5	0	50	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	2.4	2.4	2	1		0		0	50	0
		BR	ND	ND	4	0		0		0	0	0
		BR-D	ND	ND	1	0		0		0	0	0
	Silver	Spring	ND	ND	1	0	10	0	9.4	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	ND	ND	2	0		0		0	0	0
		BR	0.24	0.24	4	1		0		0	25	0
		BR-D	0.34	0.34	1	1		0		0	100	0
	Sodium	Spring	6900	6900	1	1	65600	0	NA	0	100	0
		OV-B-S	1540	48500	5	5		0		0	100	0
		OV-B / INT	1620	6100	2	2		0		0	100	0
		BR	4460	19200	4	4		0		0	100	0
		BR-D	21000	21000	1	1		0		0	100	0
	Thallium	Spring	ND	ND	1	0	5.7	0	2	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	ND	ND	2	0		0		0	0	0
		BR	ND	ND	4	0		0		0	0	0

Table 5-9

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 4**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 20 of 20)

UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Vanadium	Spring	ND	ND	1	0	50	0	8.6	0	0	0
		OV-B-S	ND	ND	5	0		0		0	0	0
		OV-B / INT	0.64	0.64	2	1		0		0	50	0
		BR	ND	ND	4	0		0		0	0	0
		BR-D	0.8	0.8	1	1		0		0	100	0
	Zinc	Spring	ND	ND	1	0	211	0	600	0	0	0
		OV-B-S	5.17	79	5	5		0		0	100	0
		OV-B / INT	11	148	2	2		0		0	100	0
		BR	6.91	16.3	4	3		0		0	75	0
		BR-D	20	20	1	1		0		0	100	0

µg/L - Micrograms per liter.

BSV - Background screening value.

MR - Most recent.

PSV - Preliminary screening value.

UTG - User test group.

<sup>(1)</sup> The Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:1) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).2) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017 *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, June, <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017>).The health advisory level is used for perchlorate (DoD, 2009, *Perchlorate Release Management Policy*, Memorandum from Wayne Army to Deputy Assistant Secretaries of the Army, Navy, and Air Force, 4 April).<sup>(2)</sup> Ratio of detected concentrations in usable samples to the total number of samples collected.<sup>(3)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of usable samples analyzed.

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 10)

Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F10-RS234	225.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	11	
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	1	U
F10-RS235	206	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	2	U
			1,1-Dichloroethane	2.8	NA	2	U
			Acetone	1400	NA	20	U
			Benzene	5	NA	2	U
			Chlorobenzene	100	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	2.78	J
			Trichloroethene	5	NA	0.58	J
			Vinyl chloride	2	NA	4.03	
		Metals	Manganese	43	3220	27.5	
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.31	U
			2,4,6-Trinitrotoluene	0.98	NA	0.31	U
			2,4-Dinitrotoluene	0.11	NA	0.31	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.31	U
			2-Nitrotoluene	0.31	NA	0.59	
			3-Nitrotoluene	0.17	NA	0.31	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.31	U
			Nitroglycerin	0.2	NA	0.78	U
			PETN	3.9	NA	0.78	U
			RDX	0.7	NA	0.19	J
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	UJ
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.01	U
F10-RS390	145.77	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	0.11	J
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	2	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	U
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.02	U

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 2 of 10)

Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F10-RS399	135.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	0.47	J
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1.04	
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	14.9	
			Vinyl chloride	2	NA	1	U
		Metals	Manganese	43	3220	12.3	J
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.32	U
			2,4,6-Trinitrotoluene	0.98	NA	0.32	U
			2,4-Dinitrotoluene	0.11	NA	0.32	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.32	U
			2-Nitrotoluene	0.31	NA	0.23	J
			3-Nitrotoluene	0.17	NA	0.32	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.32	U
			Nitroglycerin	0.2	NA	0.8	U
			PETN	3.9	NA	0.8	U
			RDX	0.7	NA	0.32	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.01	U
F10-RS488	154	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	2	U
			1,1-Dichloroethane	2.8	NA	2	U
			Acetone	1400	NA	20	U
			Benzene	5	NA	2	U
			Chlorobenzene	100	NA	2	U
			Chloroform	80	NA	0.66	J
			Methylene chloride	5	NA	4	U
			Trichloroethene	5	NA	0.96	J
			Vinyl chloride	2	NA	10.3	
		Metals	Manganese	43	3220	11.4	J
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.31	U
			2,4,6-Trinitrotoluene	0.98	NA	0.31	U
			2,4-Dinitrotoluene	0.11	NA	0.31	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.29	J
			2-Nitrotoluene	0.31	NA	0.31	U
			3-Nitrotoluene	0.17	NA	0.25	J
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.31	U
			Nitroglycerin	0.2	NA	0.74	J
			PETN	3.9	NA	0.78	U
			RDX	0.7	NA	0.21	J
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	U
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.02	U
			alpha-BHC	0.0072	NA	0.02	U
			beta-BHC	0.025	NA	0.02	U
			Dieldrin	0.0018	NA	0.02	U



Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F10-RS489	151	VOCs	1,1-Dichloroethane	2.8	NA	20	U
			Acetone	1400	NA	200	U
			Benzene	5	NA	20	U
			Chlorobenzene	100	NA	20	U
			Chloroform	80	NA	20	U
			Trichloroethene	5	NA	4.6	J
			Vinyl chloride	2	NA	170	
		Metals	Manganese	43	3220	8.86	J
F10-RS490	128	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	7.89	
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1.19	
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	7.21	
			Vinyl chloride	2	NA	1	U
		Metals	Manganese	43	3220	4.89	J
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.32	U
			2,4,6-Trinitrotoluene	0.98	NA	0.32	U
			2,4-Dinitrotoluene	0.11	NA	0.32	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.32	U
			2-Nitrotoluene	0.31	NA	0.32	U
			3-Nitrotoluene	0.17	NA	0.32	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.32	U
			Nitroglycerin	0.2	NA	0.8	U
			PETN	3.9	NA	0.8	U
			RDX	0.7	NA	0.32	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	U
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.02	U
			alpha-BHC	0.0072	NA	0.02	U
			beta-BHC	0.025	NA	0.02	
			Dieldrin	0.0018	NA	0.02	U
F10-RS491	142	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	7.46	
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	2.14	
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	10.5	
			Vinyl chloride	2	NA	1	U
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.31	U
			2,4,6-Trinitrotoluene	0.98	NA	0.31	U
			2,4-Dinitrotoluene	0.11	NA	0.31	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.31	U
			2-Nitrotoluene	0.31	NA	0.31	U
			3-Nitrotoluene	0.17	NA	0.31	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.31	U
			Nitroglycerin	0.2	NA	0.78	U
			PETN	3.9	NA	0.78	U
			RDX	0.7	NA	0.31	U

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 4 of 10)

Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F10-RS492	165	Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.01	J
			Dieldrin	0.0018	NA	0.01	U
		VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	72.7	
		Metals	Manganese	43	3220	21.7	J
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.3	U
			2,4,6-Trinitrotoluene	0.98	NA	0.3	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.3	U
			2-Nitrotoluene	0.31	NA	0.3	U
			3-Nitrotoluene	0.17	NA	0.3	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.3	U
			Nitroglycerin	0.2	NA	0.76	U
			PETN	3.9	NA	0.76	U
			RDX	0.7	NA	0.3	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	U
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.02	U
			alpha-BHC	0.0072	NA	0.02	U
			beta-BHC	0.025	NA	0.02	U
			Dieldrin	0.0018	NA	0.02	U
F10-RS494	159.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	6	J
			Vinyl chloride	2	NA	37	

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F10-RS545	138	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	17	
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	UJ
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1.4	
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	22	
			Vinyl chloride	2	NA	1	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	U
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	UJ
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.02	U
F53-RS333	159	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	6.63	J
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	45.7	
			Chloroform	80	NA	0.64	J
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	0.34	J
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.28	U
			2,4,6-Trinitrotoluene	0.98	NA	0.39	U
			2,4-Dinitrotoluene	0.11	NA	0.39	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.39	U
			2-Nitrotoluene	0.31	NA	0.39	U
			3-Nitrotoluene	0.17	NA	0.39	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.39	U
			RDX	0.7	NA	0.39	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	UJ
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.0098	U
			alpha-BHC	0.0072	NA	0.0098	UJ
			beta-BHC	0.025	NA	0.0098	U
			Dieldrin	0.0018	NA	0.02	U

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F53-RS334	141	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	0.71	J
			Chlorobenzene	100	NA	55	
			Chloroform	80	NA	1.2	
			Trichloroethene	5	NA	0.19	J
			Vinyl chloride	2	NA	2	U
		Metals	Manganese	43	3220	14	
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.004	U
			4,4'-DDE	0.046	NA	0.004	U
			Aldrin	0.00092	NA	0.00135	J
			alpha-BHC	0.0072	NA	0.0148	
			beta-BHC	0.025	NA	0.333	
			Dieldrin	0.0018	NA	0.004	U
F53-RS354	199.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	UJ
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	1	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	U
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.02	U
F53-RS355	154	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1.8	
			Chloroform	80	NA	1	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	2	U
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.27	U
			2,4,6-Trinitrotoluene	0.98	NA	0.37	U
			2,4-Dinitrotoluene	0.11	NA	0.37	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.37	U
			2-Nitrotoluene	0.31	NA	0.37	U
			3-Nitrotoluene	0.17	NA	0.37	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.37	U
			RDX	0.7	NA	0.37	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.02	U
			4,4'-DDE	0.046	NA	0.02	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.02	U

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F53-RS356	150	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	2.4	
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	2	U
		Metals	Manganese	43	3220	5340	
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.05	
			Dieldrin	0.0018	NA	0.01	U
F53-RS357	147	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	1	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.0096	U
			alpha-BHC	0.0072	NA	0.0096	U
			beta-BHC	0.025	NA	0.0096	U
F53-RS358	130.7	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	1	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.02	
			Dieldrin	0.0018	NA	0.01	U

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F53-RS562	154	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	UJ
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	14	
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	2	U
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.29	U
			2,4,6-Trinitrotoluene	0.98	NA	0.4	U
			2,4-Dinitrotoluene	0.11	NA	0.4	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.4	U
			2-Nitrotoluene	0.31	NA	0.4	U
			3-Nitrotoluene	0.17	NA	0.4	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.4	U
		Pesticides/PCBs	RDX	0.7	NA	0.4	U
			4,4'-DDD	0.032	NA	0.02	UJ
			4,4'-DDE	0.046	NA	0.02	UJ
			Aldrin	0.00092	NA	0.01	UJ
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.19	J
F60-RS291	147.7	VOCs	Dieldrin	0.0018	NA	0.02	UJ
			1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	0.62	J
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	5	U
		Metals	Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	1	U
		Pesticides/PCBs	Manganese	43	3220	97.7	
			4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.01	U

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
F60-RS362	165.5	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	1	U
		Metals	Manganese	43	3220	3.9	J
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.0096	U
			alpha-BHC	0.0072	NA	0.0096	U
			beta-BHC	0.025	NA	0.0096	U
			Dieldrin	0.0018	NA	0.01	U
F60-RS561	143	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	1	U
			Acetone	1400	NA	10	U
			Benzene	5	NA	1	U
			Chlorobenzene	100	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	1	U
			Vinyl chloride	2	NA	1	U
		Explosives	1,3-Dinitrobenzene	0.2	NA	0.27	U
			2,4,6-Trinitrotoluene	0.98	NA	0.38	U
			2,4-Dinitrotoluene	0.11	NA	0.38	U
			2-Amino-4,6-dinitrotoluene	3.9	NA	0.38	U
			2-Nitrotoluene	0.31	NA	0.38	U
			3-Nitrotoluene	0.17	NA	0.38	U
			4-Amino-2,6-dinitrotoluene	3.9	NA	0.38	U
			RDX	0.7	NA	0.38	U
		Pesticides/PCBs	4,4'-DDD	0.032	NA	0.01	U
			4,4'-DDE	0.046	NA	0.01	U
			Aldrin	0.00092	NA	0.01	U
			alpha-BHC	0.0072	NA	0.01	U
			beta-BHC	0.025	NA	0.01	U
			Dieldrin	0.0018	NA	0.01	U
MC-MW00-203Da	128.9	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	UJ
			1,1-Dichloroethane	2.8	NA	2	U
			Acetone	1400	NA	20	U
			Benzene	5	NA	2	U
			Chlorobenzene	100	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	4	U
			Trichloroethene	5	NA	2	U
			Vinyl chloride	2	NA	2	U

Table 5-10

**Analytical Summary, Deep Flow Zone Locations, Focus Area 4  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

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Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Most Recent Sample Results	
						Result	VQ
MC-MW00-203Db	175.2	VOCs	1,1,2,2-Tetrachloroethane	0.076	NA	1	UJ
			1,1-Dichloroethane	2.8	NA	2	U
			Acetone	1400	NA	20	U
			Benzene	5	NA	2	U
			Chlorobenzene	100	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	2.4	J
			Trichloroethene	5	NA	2	U
MC-MW00-203Dc	189.8	VOCs	Vinyl chloride	2	NA	2	U
			1,1,2,2-Tetrachloroethane	0.076	NA	1	UJ
			1,1-Dichloroethane	2.8	NA	2	U
			Acetone	1400	NA	20	U
			Benzene	5	NA	2	U
			Chlorobenzene	100	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	2.35	J
MC-MW00-203Dd	240.8	VOCs	Trichloroethene	5	NA	2	U
			Vinyl chloride	2	NA	2	U
			1,1,2,2-Tetrachloroethane	0.076	NA	1	U
			1,1-Dichloroethane	2.8	NA	2	U
			Acetone	1400	NA	20	U
			Benzene	5	NA	2	U
			Chlorobenzene	100	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	2.34	J
			Trichloroethene	5	NA	2	U
			Vinyl chloride	2	NA	2	U



Table 5-11

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 5**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
VOLATILES	1,1,1-Trichloroethane	OV B / INT	ND	ND	31	0	NA	0	200	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	1,1,2,2-Tetrachloroethane	OV B / INT	ND	ND	30	0	NA	0	0.076	0	0	0
		BR	0.238	0.301	8	2		0		2	25	25
	1,1,2-Trichloroethane	OV B / INT	0.29	1.9	31	3	NA	0	5	0	9.7	0
		BR	0.37	0.37	8	1		0		0	13	0
	1,1-Dichloroethane	OV B / INT	ND	ND	31	0	NA	0	2.8	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	1,1-Dichloroethene	OV B / INT	0.44	77	31	4	NA	0	7	1	13	3.2
		BR	ND	ND	8	0		0		0	0	0
	1,2,4-Trichlorobenzene	OV B / INT	ND	ND	22	0	NA	0	70	0	0	0
		BR	ND	ND	4	0		0		0	0	0
	1,2-Dichlorobenzene	OV B / INT	ND	ND	12	0	NA	0	600	0	0	0
		BR	ND	ND	4	0		0		0	0	0
	1,2-Dichloroethane	OV B / INT	ND	ND	31	0	NA	0	5	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	1,2-Dichloropropane	OV B / INT	ND	ND	31	0	NA	0	5	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	1,3-Dichlorobenzene	OV B / INT	ND	ND	21	0	NA	0	NA	0	0	0
		BR	ND	ND	4	0		0		0	0	0
	1,4-Dichlorobenzene	OV B / INT	ND	ND	22	0	NA	0	75	0	0	0
		BR	ND	ND	4	0		0		0	0	0
	2-Butanone	OV B / INT	ND	ND	31	0	NA	0	560	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	2-Hexanone	OV B / INT	ND	ND	31	0	NA	0	3.8	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	4-Methyl-2-pentanone	OV B / INT	ND	ND	31	0	NA	0	630	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Acetone	OV B / INT	38.6	120	26	2	NA	0	1400	0	7.7	0
		BR	4.1	4.1	7	1		0		0	14	0
	Benzene	OV B / INT	ND	ND	31	0	NA	0	5	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Bromodichloromethane	OV B / INT	ND	ND	31	0	NA	0	80	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Bromoform	OV B / INT	ND	ND	31	0	NA	0	80	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Bromomethane	OV B / INT	ND	ND	31	0	NA	0	0.75	0	0	0
		BR	ND	ND	8	0		0		0	0	0

Table 5-11

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 5**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Carbon disulfide	OVB / INT	ND	ND	31	0	NA	0	81	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Carbon tetrachloride	OVB / INT	0.178	11000	31	12	NA	0	5	5	39	16
		BR	0.23	0.57	8	3		0		0	38	0
	Chlorobenzene	OVB / INT	0.1	17	30	6	NA	0	100	0	20	0
		BR	0.37	1.5	8	2		0		0	25	0
	Chloroethane	OVB / INT	ND	ND	28	0	NA	0	2100	0	0	0
		BR	ND	ND	6	0		0		0	0	0
	Chloroform	OVB / INT	0.37	660	31	12	NA	0	80	2	39	6.5
		BR	0.45	1	8	2		0		0	25	0
	Chloromethane	OVB / INT	ND	ND	31	0	NA	0	19	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	cis-1,2-Dichloroethene	OVB / INT	0.326	9.1	31	11	NA	0	70	0	35	0
		BR	0.34	2.95	8	2		0		0	25	0
	cis-1,3-Dichloropropene	OVB / INT	ND	ND	31	0	NA	0	0.47	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Dibromochloromethane	OVB / INT	ND	ND	31	0	NA	0	80	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Dichlorodifluoromethane	OVB / INT	ND	ND	22	0	NA	0	20	0	0	0
		BR	ND	ND	4	0		0		0	0	0
	Ethylbenzene	OVB / INT	ND	ND	31	0	NA	0	700	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Freon 113	OVB / INT	0.828	21.5	22	8	NA	0	1000	0	36	0
		BR	0.32	0.32	4	1		0		0	25	0
	Methyl tert-butyl ether	OVB / INT	ND	ND	22	0	NA	0	14	0	0	0
		BR	ND	ND	4	0		0		0	0	0
	Methylene chloride	OVB / INT	0.33	23	30	1	NA	0	5	1	3.3	3.3
		BR	0.24	0.3	6	1		0		0	17	0
	Styrene	OVB / INT	ND	ND	31	0	NA	0	100	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	Tetrachloroethene	OVB / INT	2	3	31	1	NA	0	5	0	3.2	0
		BR	1.2	1.2	8	1		0		0	13	0
	Toluene	OVB / INT	ND	ND	31	0	NA	0	1000	0	0	0
		BR	ND	ND	8	0		0		0	0	0
	trans-1,2-Dichloroethene	OVB / INT	0.51	0.51	31	1	NA	0	100	0	3.2	0
		BR	ND	ND	8	0		0		0	0	0
	trans-1,3-Dichloropropene	OVB / INT	ND	ND	31	0	NA	0	0.47	0	0	0
		BR	ND	ND	8	0		0		0	0	0

Table 5-11

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 5**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
SEMIVOLATILES	Trichloroethene	OVB / INT	0.44	270	30	22	NA	0	5	12	73	40
		BR	0.34	26	8	6	NA	0		1	75	13
	Trichlorofluoromethane	OVB / INT	2.68	3.7	22	2	NA	0	520	0	9.1	0
		BR	ND	ND	4	0	NA	0		0	0	0
	Vinyl chloride	OVB / INT	0.801	1.17	31	2	NA	0	2	0	6.5	0
		BR	ND	ND	8	0	NA	0		0	0	0
	Xylene, Total	OVB / INT	ND	ND	31	0	NA	0	10000	0	0	0
		BR	ND	ND	8	0	NA	0		0	0	0
	1,2-Dichlorobenzene	OVB / INT	ND	ND	10	0	NA	0	600	0	0	0
	1,3-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	NA	0	0	0
	1-Methylnaphthalene	OVB / INT	ND	ND	11	0	NA	0	1.1	0	0	0
	2,4,5-Trichlorophenol	OVB / INT	ND	ND	11	0	NA	0	120	0	0	0
	2,4,6-Trichlorophenol	OVB / INT	ND	ND	11	0	NA	0	1.2	0	0	0
	2,4-Dichlorophenol	OVB / INT	ND	ND	11	0	NA	0	4.6	0	0	0
	2,4-Dimethylphenol	OVB / INT	ND	ND	11	0	NA	0	36	0	0	0
	2,4-Dinitrophenol	OVB / INT	ND	ND	11	0	NA	0	3.9	0	0	0
	2,4-Dinitrotoluene	OVB / INT	ND	ND	11	0	NA	0	0.11	0	0	0
	2,6-Dinitrotoluene	OVB / INT	ND	ND	11	0	NA	0	0.11	0	0	0
	2-Chloronaphthalene	OVB / INT	ND	ND	11	0	NA	0	75	0	0	0
	2-Chlorophenol	OVB / INT	ND	ND	11	0	NA	0	9.1	0	0	0
	2-Methylnaphthalene	OVB / INT	ND	ND	11	0	NA	0	3.6	0	0	0
	2-Methylphenol	OVB / INT	ND	ND	11	0	NA	0	93	0	0	0
	2-Nitroaniline	OVB / INT	ND	ND	11	0	NA	0	19	0	0	0
	2-Nitrophenol	OVB / INT	ND	ND	11	0	NA	0	NA	0	0	0
	3,3'-Dichlorobenzidine	OVB / INT	ND	ND	1	0	NA	0	0.13	0	0	0
	3-Nitroaniline	OVB / INT	ND	ND	11	0	NA	0	NA	0	0	0
	4,6-Dinitro-2-methylphenol	OVB / INT	ND	ND	1	0	NA	0	0.15	0	0	0
	4-Bromophenyl phenyl ether	OVB / INT	ND	ND	11	0	NA	0	NA	0	0	0
	4-Chloro-3-methylphenol	OVB / INT	ND	ND	11	0	NA	0	140	0	0	0
	4-Chloroaniline	OVB / INT	ND	ND	11	0	NA	0	0.37	0	0	0
	4-Chlorophenyl phenyl ether	OVB / INT	ND	ND	11	0	NA	0	NA	0	0	0
	4-Methylphenol	OVB / INT	ND	ND	11	0	NA	0	190	0	0	0
	4-Nitroaniline	OVB / INT	ND	ND	11	0	NA	0	3.8	0	0	0
	4-Nitrophenol	OVB / INT	ND	ND	11	0	NA	0	NA	0	0	0
	Acenaphthene	OVB / INT	ND	ND	11	0	NA	0	53	0	0	0
	Acenaphthylene	OVB / INT	ND	ND	11	0	NA	0	47	0	0	0
	Anthracene	OVB / INT	ND	ND	11	0	NA	0	180	0	0	0
	Benzo(a)anthracene	OVB / INT	ND	ND	11	0	NA	0	0.03	0	0	0
	Benzo(a)pyrene	OVB / INT	ND	ND	11	0	NA	0	0.2	0	0	0

Table 5-11

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

Focus Area 5

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
PESTICIDES/PCBS	Benzo(b)fluoranthene	OV8 / INT	ND	ND	11	0	NA	0	0.25	0	0	0
	Benzo(ghi)perylene	OV8 / INT	ND	ND	11	0	NA	0	60	0	0	0
	Benzo(k)fluoranthene	OV8 / INT	ND	ND	11	0	NA	0	2.5	0	0	0
	bis(2-Chloroethoxy)methane	OV8 / INT	ND	ND	11	0	NA	0	5.9	0	0	0
	bis(2-Chloroisopropyl)ether	OV8 / INT	ND	ND	11	0	NA	0	71	0	0	0
	bis(2-Ethylhexyl)phthalate	OV8 / INT	0.33	1.2	10	7	NA	0	6	0	70	0
	Butyl benzyl phthalate	OV8 / INT	0.31	0.39	12	2	NA	0	16	0	17	0
	Carbazole	OV8 / INT	ND	ND	11	0	NA	0	NA	0	0	0
	Chrysene	OV8 / INT	ND	ND	11	0	NA	0	25	0	0	0
	Dibenzofuran	OV8 / INT	ND	ND	11	0	NA	0	0.79	0	0	0
	Diethyl phthalate	OV8 / INT	0.2	0.86	8	2	NA	0	1500	0	25	0
	Dimethyl phthalate	OV8 / INT	0.32	0.32	11	1	NA	0	NA	0	9.1	0
	Di-n-butyl phthalate	OV8 / INT	0.39	3.1	5	2	NA	0	90	0	40	0
	Di-n-octyl phthalate	OV8 / INT	ND	ND	11	0	NA	0	20	0	0	0
	Fluoranthene	OV8 / INT	ND	ND	11	0	NA	0	80	0	0	0
	Fluorene	OV8 / INT	ND	ND	11	0	NA	0	29	0	0	0
	Hexachlorobenzene	OV8 / INT	ND	ND	11	0	NA	0	1	0	0	0
	Hexachlorobutadiene	OV8 / INT	ND	ND	11	0	NA	0	0.14	0	0	0
	Hexachlorocyclopentadiene	OV8 / INT	ND	ND	11	0	NA	0	50	0	0	0
	Hexachloroethane	OV8 / INT	ND	ND	11	0	NA	0	0.33	0	0	0
	Indeno(1,2,3-cd)pyrene	OV8 / INT	ND	ND	11	0	NA	0	0.25	0	0	0
	Isophorone	OV8 / INT	ND	ND	11	0	NA	0	78	0	0	0
	Naphthalene	OV8 / INT	ND	ND	11	0	NA	0	0.17	0	0	0
	Nitrobenzene	OV8 / INT	0.41	0.41	11	0	NA	0	0.14	0	0	0
	n-Nitrosodiphenylamine	OV8 / INT	ND	ND	11	0	NA	0	12	0	0	0
	Pentachlorophenol	OV8 / INT	ND	ND	11	0	NA	0	1	0	0	0
	Phenanthrene	OV8 / INT	ND	ND	11	0	NA	0	18	0	0	0
	Phenol	OV8 / INT	0.29	0.7	11	2	NA	0	580	0	18	0
	Pyrene	OV8 / INT	ND	ND	11	0	NA	0	12	0	0	0
	4,4'-DDD	OV8 / INT	ND	ND	2	0	NA	0	0.032	0	0	0
	4,4'-DDE	OV8 / INT	ND	ND	2	0	NA	0	0.046	0	0	0
	4,4'-DDT	OV8 / INT	ND	ND	2	0	NA	0	0.23	0	0	0
	Aldrin	OV8 / INT	ND	ND	2	0	NA	0	0.00092	0	0	0
	alpha-BHC	OV8 / INT	ND	ND	2	0	NA	0	0.0072	0	0	0
	alpha-Chlordane	OV8 / INT	ND	ND	2	0	NA	0	2	0	0	0
	beta-BHC	OV8 / INT	ND	ND	2	0	NA	0	0.025	0	0	0
	delta-BHC	OV8 / INT	ND	ND	2	0	NA	0	0.36	0	0	0
	Dieldrin	OV8 / INT	ND	ND	2	0	NA	0	0.0018	0	0	0
	Endosulfan I	OV8 / INT	ND	ND	2	0	NA	0	10	0	0	0

Table 5-11

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 5**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
EXPLOSIVES	Endosulfan II	OVB / INT	0.01	0.01	2	1	NA	0	10	0	50	0
	Endosulfan sulfate	OVB / INT	ND	ND	2	0	NA	0	10	0	0	0
	Endrin	OVB / INT	ND	ND	2	0	NA	0	2	0	0	0
	Endrin aldehyde	OVB / INT	ND	ND	2	0	NA	0	0.23	0	0	0
	Endrin ketone	OVB / INT	ND	ND	2	0	NA	0	0.23	0	0	0
	gamma-BHC (Lindane)	OVB / INT	ND	ND	2	0	NA	0	0.2	0	0	0
	gamma-Chlordane	OVB / INT	ND	ND	2	0	NA	0	2	0	0	0
	Heptachlor	OVB / INT	ND	ND	2	0	NA	0	0.4	0	0	0
	Heptachlor epoxide	OVB / INT	ND	ND	2	0	NA	0	0.2	0	0	0
	Methoxychlor	OVB / INT	ND	ND	2	0	NA	0	40	0	0	0
	Toxaphene	OVB / INT	ND	ND	2	0	NA	0	3	0	0	0
	1,3,5-Trinitrobenzene	OVB / INT	ND	ND	2	0	NA	0	59	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	1,3-Dinitrobenzene	OVB / INT	ND	ND	2	0	NA	0	0.2	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	2,4,6-Trinitrotoluene	OVB / INT	ND	ND	2	0	NA	0	0.98	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	2,4-Dinitrotoluene	OVB / INT	ND	ND	2	0	NA	0	0.11	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	2,6-Dinitrotoluene	OVB / INT	ND	ND	2	0	NA	0	0.11	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	2-Amino-4,6-dinitrotoluene	OVB / INT	ND	ND	2	0	NA	0	3.9	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	2-Nitrotoluene	OVB / INT	ND	ND	2	0	NA	0	0.31	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	3-Nitrotoluene	OVB / INT	ND	ND	2	0	NA	0	0.17	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	4-Amino-2,6-dinitrotoluene	OVB / INT	ND	ND	2	0	NA	0	3.9	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	HMX	OVB / INT	ND	ND	2	0	NA	0	100	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	Nitrobenzene	OVB / INT	0.41	0.41	2	1	NA	0	0.14	1	50	50
		BR	0.235	0.235	1	1	NA	0		1	100	100
	Nitroglycerin	OVB / INT	ND	ND	2	0	NA	0	0.2	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0
	PETN	OVB / INT	ND	ND	2	0	NA	0	3.9	0	0	0
		BR	ND	ND	1	0	NA	0		0	0	0

Table 5-11

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 5**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
METALS	p-Nitrotoluene	OVB / INT	ND	ND	2	0	NA	0	4.3	0	0	0
		BR	ND	ND	1	0		0		0	0	0
	RDX	OVB / INT	ND	ND	2	0	NA	0	0.7	0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Tetryl	OVB / INT	ND	ND	2	0	NA	0	3.9	0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Aluminum	OVB / INT	7.6	855	15	15	9434	0	2000	0	100	0
		BR	236	236	1	1		0		0	100	0
	Antimony	OVB / INT	ND	ND	15	0	17	0	6	0	0	0
		BR	ND	ND	1	0		0		0	0	0
	Arsenic	OVB / INT	0.84	340	25	8	5.1	4	10	2	32	8
		BR	ND	ND	6	0		0		0	0	0
	Barium	OVB / INT	7.4	90.4	15	15	156	0	2000	0	100	0
		BR	61.6	61.6	1	1		0		0	100	0
	Beryllium	OVB / INT	0.28	0.58	15	3	5	0	4	0	20	0
		BR	ND	ND	1	0		0		0	0	0
	Cadmium	OVB / INT	0.27	2.4	15	4	5	0	5	0	27	0
		BR	ND	ND	1	0		0		0	0	0
	Calcium	OVB / INT	3900	95000	15	15	144000	0	NA	0	100	0
		BR	43100	43100	1	1		0		0	100	0
	Chromium	OVB / INT	0.96	4.6	15	10	16	0	100	0	67	0
		BR	ND	ND	1	0		0		0	0	0
	Cobalt	OVB / INT	0.14	30	15	9	50	0	0.6	3	60	0
		BR	ND	ND	1	0		0		0	0	0
	Copper	OVB / INT	0.91	5.19	15	10	25	0	1300	0	67	0
		BR	ND	ND	1	0		0		0	0	0
	Iron	OVB / INT	74.5	1960	15	11	12100	0	1400	2	73	0
		BR	173	173	1	1		0		0	100	0
	Lead	OVB / INT	0.26	0.6	15	7	5.2	0	15	0	47	0
		BR	ND	ND	1	0		0		0	0	0
	Magnesium	OVB / INT	760	12000	15	15	19414	0	NA	0	100	0
		BR	28300	28300	1	1		1		0	100	0
	Manganese	OVB / INT	1.4	2540	15	15	3220	0	43	8	100	0
		BR	67.1	67.1	1	1		0		1	100	0
	Mercury	OVB / INT	0.03	9.9	19	9	0.2	3	2	1	47	5.3
		BR	ND	ND	1	0		0		0	0	0

Table 5-11

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 5**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

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UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
	Nickel	OVB / INT	0.93	9.87	15	12	40	0	100	0	80	0
		BR	ND	ND	1	0		0		0	0	0
	Potassium	OVB / INT	120	3690	15	11	5810	0	NA	0	73	0
		BR	ND	ND	1	0		0		0	0	0
	Selenium	OVB / INT	1.5	2.1	15	4	5	0	50	0	27	0
		BR	ND	ND	1	0		0		0	0	0
	Silver	OVB / INT	0.18	0.18	15	1	10	0	9.4	0	6.7	0
		BR	ND	ND	1	0		0		0	0	0
	Sodium	OVB / INT	1370	8700	15	15	65600	0	NA	0	100	0
		BR	6730	6730	1	1		0		0	100	0
	Thallium	OVB / INT	0.2	0.2	15	1	5.7	0	2	0	6.7	0
		BR	ND	ND	1	0		0		0	0	0
	Vanadium	OVB / INT	0.57	12	16	9	50	0	8.6	1	56	0
		BR	ND	ND	1	0		0		0	0	0
	Zinc	OVB / INT	8.92	64	15	14	211	0	600	0	93	0
		BR	ND	ND	1	0		0		0	0	0

µg/L - Micrograms per liter.

BSV - Background screening value.

MR - Most recent.

PSV - Preliminary screening value.

UTG - User test group.

<sup>(1)</sup> The Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:

- 1) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).
- 2) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017 *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, June, <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017>). The health advisory level is used for perchlorate (DoD, 2009, *Perchlorate Release Management Policy*, Memorandum from Wayne Army to Deputy Assistant Secretaries of the Army, Navy, and Air Force, 4 April).

<sup>(2)</sup> Ratio of detected concentrations in usable samples to the total number of samples collected.<sup>(3)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of usable samples analyzed.

**Table 5-12**

**Analytical Summary, Deep Flow Zone Locations, Focus Area 5  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 2)

						Most Recent Sample Results	
Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Result	VQ
249-RS2866	97.32	VOCs	1,1-Dichloroethene	7	NA	1	nv
			Carbon tetrachloride	5	NA	1	nv
			Chloroform	80	NA	0.312	J
			Methylene chloride	5	NA	2	nv
			Trichloroethene	5	NA	1	nv
E-RS1099	125.75	VOCs	1,1-Dichloroethene	7	NA	1	U
			Carbon tetrachloride	5	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	0.48	J
		Metals	Arsenic	10	5.1	10	U
F10-RS545	138	VOCs	1,1-Dichloroethene	7	NA	1	U
			Carbon tetrachloride	5	NA	0.52	J
			Chloroform	80	NA	1.4	
			Methylene chloride	5	NA	5	U
			Trichloroethene	5	NA	22	
F54-RS301	143.5	VOCs	1,1-Dichloroethene	7	NA	1	U
			Carbon tetrachloride	5	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	1	U
F54-RS302	146	VOCs	1,1-Dichloroethene	7	NA	1	U
			Carbon tetrachloride	5	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	1	U
		Explosives	Nitrobenzene	0.14	NA	0.24	U
MC-MW00-204Dc	159	VOCs	1,1-Dichloroethene	7	NA	2.18	J
			Carbon tetrachloride	5	NA	5	U
			Chloroform	80	NA	5	U
			Methylene chloride	5	NA	10	U
			Trichloroethene	5	NA	5	U
MC-MW00-204Dd	166.5	VOCs	1,1-Dichloroethene	7	NA	2.07	J
			Carbon tetrachloride	5	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	4	U
			Trichloroethene	5	NA	0.52	J
MC-MW00-204De	255	VOCs	1,1-Dichloroethene	7	NA	2	U
			Carbon tetrachloride	5	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	4	U
			Trichloroethene	5	NA	2	U



Table 5-12

**Analytical Summary, Deep Flow Zone Locations, Focus Area 5  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 2 of 2)

						Most Recent Sample Results	
Location Code	Depth, Bottom of Screened Interval (ft bgs)	User Test Group	Parameter	PSV	BSV	Result	VQ
MC-MW00-208D	141	VOCs	1,1-Dichloroethene	7	NA	1	U
			Carbon tetrachloride	5	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	0.62	J
MC-MW00-213D	161	VOCs	1,1-Dichloroethene	7	NA	4.2	=
			Carbon tetrachloride	5	NA	1	U
			Chloroform	80	NA	1	U
			Methylene chloride	5	NA	2	U
			Trichloroethene	5	NA	8	=
MC-MW00-403Db	215.5	VOCs	1,1-Dichloroethene	7	NA	2	U
			Carbon tetrachloride	5	NA	2	U
			Chloroform	80	NA	2	U
			Methylene chloride	5	NA	4	U
			Trichloroethene	5	NA	2	U
		Metals	Arsenic	10	5.1	9.73	J
			Mercury	2	0.2	0.2	U
T-RS1144	165.75	VOCs	1,1-Dichloroethene	7	NA	1	U
			Carbon tetrachloride	5	NA	1	U
			Chloroform	80	NA	1	U
			Trichloroethene	5	NA	1	U

Table 5-13

**Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results**  
**Focus Area 6**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

(Page 1 of 2)

UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
VOLATILES	1,1,1-Trichloroethane	OVB / INT	ND	ND	1	0	NA	0	200	0	0	0
	1,1,2,2-Tetrachloroethane	OVB / INT	ND	ND	1	0	NA	0	0.076	0	0	0
	1,1,2-Trichloroethane	OVB / INT	ND	ND	1	0	NA	0	5	0	0	0
	1,1-Dichloroethane	OVB / INT	ND	ND	1	0	NA	0	2.8	0	0	0
	1,1-Dichloroethene	OVB / INT	ND	ND	1	0	NA	0	7	0	0	0
	1,2,4-Trichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	70	0	0	0
	1,2-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	600	0	0	0
	1,2-Dichloroethane	OVB / INT	ND	ND	1	0	NA	0	5	0	0	0
	1,2-Dichloropropane	OVB / INT	ND	ND	1	0	NA	0	5	0	0	0
	1,3-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	NA	0	0	0
	1,4-Dichlorobenzene	OVB / INT	ND	ND	1	0	NA	0	75	0	0	0
	2-Butanone	OVB / INT	ND	ND	1	0	NA	0	560	0	0	0
	2-Hexanone	OVB / INT	ND	ND	1	0	NA	0	3.8	0	0	0
	4-Methyl-2-pentanone	OVB / INT	ND	ND	1	0	NA	0	630	0	0	0
	Acetone	OVB / INT	ND	ND	1	0	NA	0	1400	0	0	0
	Benzene	OVB / INT	ND	ND	1	0	NA	0	5	0	0	0
	Bromodichloromethane	OVB / INT	ND	ND	1	0	NA	0	80	0	0	0
	Bromoform	OVB / INT	ND	ND	1	0	NA	0	80	0	0	0
	Bromomethane	OVB / INT	ND	ND	1	0	NA	0	0.75	0	0	0
	Carbon disulfide	OVB / INT	ND	ND	1	0	NA	0	81	0	0	0
	Carbon tetrachloride	OVB / INT	ND	ND	1	0	NA	0	5	0	0	0
	Chlorobenzene	OVB / INT	ND	ND	1	0	NA	0	100	0	0	0
	Chloroethane	OVB / INT	ND	ND	1	0	NA	0	2100	0	0	0
	Chloroform	OVB / INT	ND	ND	1	0	NA	0	80	0	0	0
	Chloromethane	OVB / INT	ND	ND	1	0	NA	0	19	0	0	0
	cis-1,2-Dichloroethene	OVB / INT	ND	ND	1	0	NA	0	70	0	0	0
	cis-1,3-Dichloropropene	OVB / INT	ND	ND	1	0	NA	0	0.47	0	0	0
	Dibromochloromethane	OVB / INT	ND	ND	1	0	NA	0	80	0	0	0
	Dichlorodifluoromethane	OVB / INT	ND	ND	1	0	NA	0	20	0	0	0
	Ethylbenzene	OVB / INT	ND	ND	1	0	NA	0	700	0	0	0
	Freon 113	OVB / INT	ND	ND	1	0	NA	0	1000	0	0	0
	Methyl tert-butyl ether	OVB / INT	ND	ND	1	0	NA	0	14	0	0	0
	Methylene chloride	OVB / INT	ND	ND	1	0	NA	0	5	0	0	0
	Styrene	OVB / INT	ND	ND	1	0	NA	0	100	0	0	0

Table 5-13

## Statistical Summary of Chemicals that Exceed PSVs in Groundwater, Most Recent Results

## Focus Area 6

RSA-147/148/149

Redstone Arsenal, Madison County, Alabama

(Page 2 of 2)

UTG	Parameter	Sample Zone	Min MR Conc by Focus Area (µg/L)	Max MR Conc by Focus Area (µg/L)	Total Usable Samples	Detections in Usable Samples	BSV (µg/L)	Detections Above BSV	2017 PSV <sup>(1)</sup> (µg/L)	Detections Above PSV	Detection Frequency <sup>(2)</sup> (%)	Exceedance Frequency <sup>(3)</sup> (%)
VOLATILES	Tetrachloroethene	OVB / INT	ND	ND	1	0	NA	0	5	0	0	0
	Toluene	OVB / INT	ND	ND	1	0	NA	0	1000	0	0	0
	trans-1,2-Dichloroethene	OVB / INT	ND	ND	1	0	NA	0	100	0	0	0
	trans-1,3-Dichloropropene	OVB / INT	ND	ND	1	0	NA	0	0.47	0	0	0
	Trichloroethene	OVB / INT	7.19	7.19	1	1	NA	0	5	1	100	100
	Trichlorofluoromethane	OVB / INT	ND	ND	1	0	NA	0	520	0	0	0
	Vinyl chloride	OVB / INT	ND	ND	1	0	NA	0	2	0	0	0
	Xylene, Total	OVB / INT	ND	ND	1	0	NA	0	10000	0	0	0

µg/L - Micrograms per liter.

BSV - Background screening value.

MR - Most recent.

PSV - Preliminary screening value.

UTG - User test group.

<sup>(1)</sup> The Redstone-specific preliminary screening levels (PSV) for groundwater are determined by the following hierarchy:1) Maximum contaminant level (EPA, 2012, *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, Washington, District of Columbia, April).2) Tap water regional screening levels (RSL), adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 or a hazard index of 0.1 (EPA, 2017, *Regional Screening Levels for Chemical Contaminants at Superfund Sites, Mid-Atlantic Risk Assessment*, June, <https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017>).The health advisory level is used for perchlorate (DoD, 2009, *Perchlorate Release Management Policy*, Memorandum from Wayne Army to Deputy Assistant Secretaries of the Army, Navy, and Air Force, 4 April).<sup>(2)</sup> Ratio of detected concentrations in usable samples to the total number of samples collected.<sup>(3)</sup> Ratio of concentrations greater than PSV (and BSV for metals) to the number of usable samples analyzed.

**Table 5-14**

**Analytical Summary, Deep Flow Zone Locations, Focus Area 6  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

					<b>Most Recent Sample Results</b>	
<b>Location Code</b>	<b>Depth, Bottom of Screened Interval (ft bgs)</b>	<b>User Test Group</b>	<b>Parameter</b>	<b>PSV</b>	<b>Result</b>	<b>VQ</b>
MC-MW00-302Dc	128	VOCs	Trichloroethene	5	2	U
MC-MW00-302Dd	150	VOCs	Trichloroethene	5	4.44	=
MC-MW00-302De	178.5	VOCs	Trichloroethene	5	3.59	=
MC-MW00-302Df	182	VOCs	Trichloroethene	5	2	U
MC-MW00-602Da	161.1	VOCs	Trichloroethene	5	2	U
MC-MW00-602Db	197.55	VOCs	Trichloroethene	5	2	U
MC-MW00-602Dc	207.5	VOCs	Trichloroethene	5	2	U

**Table 6-1**  
**Physical Properties of Contaminants of Interest**  
**RSA-147/148/149 Groundwater Units**  
**Redstone Arsenal, Madison County, Alabama**

(Page 1 of 2)

Compound	CAS No.	S (mg/L) Literature	1% S (µg/L)	H (at 25°C) (atm-m <sup>3</sup> /mol)	Vp (mm Hg)	B.P. (C)	K <sub>oc</sub> (mL/g)	Log K <sub>ow</sub>	Density (g/cm <sup>3</sup> )	MW	Source
<b>Volatile Organic Compounds</b>											
Tetrachloroethane	127-18-4	200	2,000	1.74E-02	18.9	121.40	364	2.53	1.63	165.8	A
Trichloroethene	79016	1,100	11,000	9.37E-03	75	86.70	126	2.53	1.46	131.5	A
1,1,2,2-Tetrachloroethane	79-34-5	2,830	28,300	3.67E-04	4.62	146.50	79	2.39	1.60	167.9	B/C
1,1-DCE	75-35-4	2,420	24,200	2.61E-02	600	31.70	59	2.113	1.21	96.94	D
Carbon tetrachloride	56-23-5	793	7,930	2.76E-02	115	76.80	158	2.83	1.59	153.82	D/E
cis-1,2-Dichloroethene	156-59-2	6,410	64,100	4.08E-03	200	60.10	240	1.86	1.28	96.94	B
Chlorobenzene	108-90-7	498	4,980	3.11E-02	12	131.70	219	2.84	1.06	112.56	D / E
1,1-Dichloroethane	75-34-3	5,040	50,400	5.62E-03	227	57.40	30	1.79	1.17	98.97	B
1,1-Dichloroethene	75-35-4	2,420	24,200	2.61E-02	600	31.70	59	2.113	1.21	96.94	B
Vinyl Chloride	75-01-4	8,800	88,000	2.78E-02	2980	-13.30	57	1.23	0.91	62.5	B
Chloroform	67-66-3	7,950	79,500	3.39E-03	160	61.70	34 - 196	1.97	1.48	119.38	B/D
Methylene chloride	75-09-2	13,200	132,000	3.25E-03	435	40.00	8 - 48	1.25	1.33	84.93	B/D
1,2-Dichloroethane	107-06-2	8,600	86,000	1.18E-03	78.9	83.50	33	1.48	1.24	98.96	D
Carbon disulfide	75-15-0	2,160	21,600	1.44E-02	359	46.20	270	2.16	1.94	76.13	D
1,1,2-Trichloroethane	79-00-5	4,590	45,900	8.24E-04	23	113.80	83 - 209	1.89	1.44	133.4	D
Methyl tert- butyl ether	1634-04-4	51,000	510,000	5.87E-04	250	55.20	11 - 12	0.94	0.74	88.15	D
Acetone	67-64-1	miscible	miscible	3.97E-05	231	56.20	1	-0.24	0.79	58.08	D
Bromomethane	74-97-5	16,700	167,000	1.44E-03	142	68.10	24	1.41	1.93	129.39	B/D
Benzene	71-43-2	1,790	17,900	5.55E-03	95	80.10	85	2.13	0.87	78.12	B/D
<b>Semivolatile Organic Compounds</b>											
Naphthalene	91-20-3	31	310	4.40E-04	0.085	217.90	1,231	3.3	1.16	128.17	D / E
Benzo(a)anthracene	56-55-3	9,430	94,300	6.60E-07	5.00E-09	437.60	459,882	5.79	---	228.29	D/E/B
Dibenz(a,h)anthracene	53-70-3	0.00249	0.0249	6.60E-07	9.55E-10	524	2.03E+06	6.75	1.28	278.33	D/E/B
<b>Pesticides</b>											
Aldrin	309-00-2	170	1700	4.40E-05	1.20E-04	145.00	400 - 28,000	6.5	1.70	364.91	D
Dieldrin	60-57-1	0.195	1.95	1.00E-05	5.89E-06	Solid	1,957 - 23,310	5.4	1.75	380.91	D
beta-BHC	319-85-7	0.700	7	2.30E-07	1.70E-01	60.00	3.4 - 4.1	3.8	1.89	290.83	B/D
alpha-BHC	319-84-6	2.000	20	6.68E-06	4.50E-05	288.00	1,780 - 1,995	3.81	1.87	290.83	B/D
4,4'-DDT	50-29-3	0.0055	0.055	8.32E-06	1.60E-07	260.00	1.13E05 - 3.5E05	6.91	0.98	354.49	D
4,4'-DDD	72-54-8	0.090	0.90	6.60E-06	1.35E-06	193.00	130,600 - 131,800	6.02	1.48	320.05	D
4,4'-DDE	72-55-9	0.040	0.40	4.16E-05	6.00E-06	---	26,300 - 75,860	6.51	---	318.03	D
Heptachlor epoxide	1024-57-3	0.040	0.40	3.16E-05	2.60E-06	---	7,800	3.65	---	389.32	B
Arochlor 1242	53469-21-9	0.240	2.40	3.43E-04	1.30E-03	325-366	78,000	4.11	1.38	261.00	D
gamma-BHC (Lindane)	58-89-9	7.000	70.00	4.93E-07	9.40E-06	323.40	1,080	3.24	1.89	290.83	B/D
delta-BHC	319-86-8	21.300	213	2.50E-07	2.00E-02	60.00	700 - 2,700	4.14	1.87	290.83	B/D
Arochlor 1016	12674-11-2	0.420	4.20	2.00E-04	4.00E-04	323-356	52,100 - 171,000	4.38	1.33	---	D
Arochlor 1254	11097-69-1	0.057	0.57	2.83E-04	7.71E-05	365-390	4.6 - 6.1	6.3	1.50	327.00	D
Toxaphene	8001-35-2	0.500	5.00	4.89E-03	2.00E-01	---	2.1E05 - 1.0E06	3.3	1.60	413.82	B/D

**Table 6-1**  
**Physical Properties of Contaminants of Interest**  
**RSA-147/148/149 Groundwater Units**  
**Redstone Arsenal, Madison County, Alabama**

(Page 2 of 2)

Compound	CAS No.	S (mg/L)	1% S	H (at 25°C)	Vp	B.P.	K <sub>oc</sub>	Log K <sub>ow</sub>	Density	MW	Source
		Literature	(µg/L)	(atm·m <sup>3</sup> /mol)	(mm Hg)	(°C)	(mL/g)		(g/cm <sup>3</sup> )		
Endrin aldehyde	7421-93-4	0.260	2.60	3.86E-07	2.00E-07	— <sup>b</sup>	4,300	5.6	—	380.92	B/D
Endrin	72-20-8	0.260	2.60	4.00E-07	2.00E-07	— <sup>c</sup>	11,420	5.6	1.65	380.92	B/D
alpha-Chlordane	57-74-9	0.056	0.56	4.79E-05	1.00E-05	175.00	20,000 - 76,000	2.78	1.61	409.80	B/D
Arochlor 1260	11096-82-5	0.080	0.80	3.36E-04	4.05E-05	385-420	4.8 - 6.8	6.8	1.57	375.70	D
Heptachlor	76-44-8	0.056	0.56	1.48E-03	3.00E-04	145.00	13,330 - 661,000	4.4	1.57	373.32	B/D
<b>Explosive Compounds</b>											
2-Nitrotoluene	88-72-2	650	6500	1.25E-05	0.188	222.00	370	2.3	1.162	137.14	D/G
Nitrobenzene	98-95-3	2,090	20900	2.40E-05	0.245	210.80	141	1.85	1.2037	123.11	D / E
1,3-Dinitrobenzene	99-65-0	533	5330	4.90E-08	2.00E-04	302.80	150	1.49	1.575	168.11	D/G
Nitroglycerin	55-63-0	1,800	18000	4.30E-08	2.00E-04	218.00	180	1.62	1.592	227.09	G
2,6-Dinitrotoluene	606-20-2	204	2040	6.70E-07	5.67E-04	285.00	19; 72; 197	2.1	1.283	182.15	G
3-Nitrotoluene	99-08-1	500	5,000	9.3X10-6	0.11	232.0	363	2.45	1.16	137.14	G
2,4-Dinitrotoluene	121-14-2	200	2000	5.40E-08	1.47E-04	300.00	57 - 2,000	1.98	1.321	182.14	D/F
RDX	121-82-4	59.7	597	2.00E-11	4.10E-09	276 - 280	42-167	0.87	1.82	222.12	B
4-Amino-2,6-dinitrotoluene	19406-51-0	—	—	—	—	—	—	—	—	197.15	G
2-Amino-4,6-dinitrotoluene	35572-78-2	—	—	—	—	—	—	—	—	197.15	G
Tetryl	479-45-8	80	800	2.70E-09	1.20E-07	187.00	2100	1.64	1.5700	287.14	D/G

**Notes:**

Abs Viscosity - Absolute viscosity in cP (centipoise).

cS - Centistokes; units of kinematic viscosity.

µg/L - Micrograms per liter.

S - Solubility in milligrams per liter (mg/L).

H<sup>c</sup> - Henry's Constant.

H - Henry's Constant at 25 degrees Celsius in cubic meters of atmosphere per mole (atm·m<sup>3</sup>/mol).

MW - Molecular weight.

Vp - Vapor Pressure in millimeters of mercury (mm·Hg).

B.P. - Boiling point in degrees Celsius.

K<sub>oc</sub> - Partition coefficient of organic carbon in milliliters per gram (mL/g).

Log K<sub>ow</sub> - Partition coefficient of octanol.

<sup>a</sup> - decomposes above 120° C

<sup>b</sup> - decomposes above 235° C

<sup>c</sup> - decomposes above 245° C

**Sources:**

A - Pankow, J.F. and J.A. Cherry, 1996, *Dense Chlorinated Solvents and other DNAPLs in Groundwater*, Waterloo Press, p. 509.

B - U.S. Environmental Protection Agency, 1992, *Handbook of RCRA Ground-water Monitoring Constituents Chemical Physical Properties*, PB92-233287.

C - U.S. Environmental Protection Agency, 2004, *Users Guide for Evaluating Subsurface Vapor Intrusion into Buildings*.

D - National Library of Medicine, TOXNET (online at <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>); last modified December 2011.

E - U.S. Environmental Protection Agency, 1996, *Soil Screening Guidance, Users Guide*, Office of Solid Waste and Emergency Response, EPA/540/R-95/128, May.

F - <http://www.sciencelab.com/msds.php>

G - <http://www.pubchem.ncbi.nlm.nih.gov>

Table 6-2

**Summary of Groundwater Concentration Trends for the Five Dominant Groundwater Chemicals of Concern  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

		TCE		Carbon Tetrachloride		Chlorobenzene		4,4,4-DDD		beta-BHC	
<b>Total Locations</b>		198		198		198		198		198	
<b>Non-Detect</b>		19		114		94		107		78	
<b>Not Sampled</b>		0		0		0		58		59	
<b>Detected/Sampled</b>		179		84		104		33		61	
<b>Trend</b>	<b>No Change</b>	4 <sup>a</sup>	2.2% <sup>b</sup>	2 <sup>a</sup>	2.4% <sup>b</sup>	9 <sup>a</sup>	8.7% <sup>b</sup>	13 <sup>a</sup>	39.4% <sup>b</sup>	12 <sup>a</sup>	19.7% <sup>b</sup>
	<b>Declining Concentration</b>	158 <sup>a</sup>	88.3% <sup>b</sup>	74 <sup>a</sup>	88.1% <sup>b</sup>	83 <sup>a</sup>	79.8% <sup>b</sup>	17 <sup>a</sup>	51.5% <sup>b</sup>	46 <sup>a</sup>	75.4% <sup>b</sup>
	percent decline (min) <sup>c</sup>	2.5%		1.6%		4.2%		19.0%		0.1%	
	percent decline (max) <sup>c</sup>	100%		100%		100.0%		100.0%		100.0%	
	percent decline (avg) <sup>d</sup>	77.2%		81.3%		73.2%		92.6%		73.6%	
	<b>Increasing Concentration</b>	17 <sup>a</sup>	9.5% <sup>b</sup>	8 <sup>a</sup>	9.5% <sup>b</sup>	12 <sup>a</sup>	11.5% <sup>b</sup>	2 <sup>a</sup>	6.1% <sup>b</sup>	3 <sup>a</sup>	4.9% <sup>b</sup>
	percent increase (min) <sup>c</sup>	21.4%		13.5%		10.4%		86.0%		6.6%	
	percent increase (max) <sup>c</sup>	99.6%		99.5%		98.2%		98.2%		80.9%	
	percent increase (avg) <sup>d</sup>	72.0%		60.0%		85.0%		92.0%		45.8%	

Trend is based on comparison of the most recent concentration to the historic maximum concentration

a - Number of locations.

b - Percent of locations where detected/sampled.

c - Percent decline or increase in concentration over time.

d - Average of the percent concentration decline or increase.

Table 6-3a

**Analytical Results of VOCs for Collocated Groundwater, Spring, Surface Water, and Sediment Samples  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 3)

Sample Location	Sample Type and Location	Sample Date	TCE Concentration	1,1,2,2-TeCA Concentration	Tetrachloroethene Concentration	Chlorobenzene Concentration	Carbon Tetrachloride Concentration
RSP-0373	Groundwater from spring (µg/L)	10-Feb-12	1 U	1 U	1 UJ	1 U	1 U
RSP-0373	Surface water at spring (µg/L)	10-Feb-12	1 U	1 U	1 UJ	1 U	1 U
RSP-0373x	Surface water downstream of spring (µg/L)	10-Feb-12	1 U	1 U	1 UJ	1 U	1 U
RSP-0373	Sediment at spring (mg/kg)	10-Feb-12	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
RSP-0373x	Sediment downstream of spring (mg/kg)	10-Feb-12	0.0067 U	0.0067 U	0.0067 U	0.0067 U	0.0067 U
RSP-0385	Groundwater from spring (µg/L)	23-Jan-12	1 U	1 U	1 U	1 U	1 U
RSP-0385	Surface water at spring (µg/L)	23-Jan-12	1 U	1 U	1 U	1 U	1 U
RSP-0385x	Surface water downstream of spring (µg/L)	23-Jan-12	1 U	1 U	1 U	1 U	1 U
RSP-0385	Sediment at spring (mg/kg)	23-Jan-12	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
RSP-0385x	Sediment downstream of spring (mg/kg)	23-Jan-12	0.007 U	0.007 U	0.007 U	0.007 U	0.007 U
RSP-0504	Groundwater from spring (µg/L)	18-Jan-12	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
RSP-0504	Surface water at spring (µg/L)	18-Jan-12	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
RSP-0504x	Surface water downstream of spring (µg/L)	18-Jan-12	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
RSP-0504	Sediment at spring (mg/kg)	18-Jan-12	0.0076 U	0.0076 U	0.0076 U	0.0076 U	0.0076 U
RSP-0504x	Sediment downstream of spring (mg/kg)	18-Jan-12	0.0074 U	0.0074 U	0.0074 U	0.0074 U	0.0074 U
RSP-0568	Groundwater from spring (µg/L)	15-Feb-12	1 U	1 U	1 U	1 U	1 U
RSP-0568	Surface water at spring (µg/L)	15-Feb-12	1 U	1 U	1 U	1 U	1 U
RSP-0568x	Surface water downstream of spring (µg/L)	15-Feb-12	1 U	1 U	1 U	1 U	1 U
RSP-0568	Sediment at spring (mg/kg)	15-Feb-12	0.0066 U	0.0066 U	0.0066 U	0.0066 U	0.0066 U
RSP-0568x	Sediment downstream of spring (mg/kg)	15-Feb-12	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-0780a	Groundwater from spring (µg/L)	23-Mar-09	51	0.23 J	9.9	1 U	1 U
RSP-0780a	Surface water at spring (µg/L)	23-Mar-09	48 J	0.24 J	9.1	1 U	5.9 J
RSP-0780ax	Surface water downstream of spring (µg/L)	23-Mar-09	50	1 U	9.3	1 U	5.9 J
RSP-0780a	Sediment at spring (mg/kg)	23-Mar-09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-0780ax	Sediment downstream of spring (mg/kg)	23-Mar-09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-0820	Groundwater from spring	18-Mar-09	4.7	2	0.18 J	1 U	0.46 J
RSP-0820	Surface water at spring	19-Mar-09	4	1.8	1 UJ	1 U	0.33 J
RSP-0820x	Surface water downstream of spring	18-Mar-09	4.8	2	1 UJ	1 U	0.44 J
RSP-0820	Sediment at spring (mg/kg)	18-Mar-09	0.0088 U	0.0088 U	0.0088 U	0.0088 U	0.0088 U



Table 6-3a

**Analytical Results of VOCs for Collocated Groundwater, Spring, Surface Water, and Sediment Samples  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 2 of 3)

Sample Location	Sample Type and Location	Sample Date	TCE Concentration	1,1,2,2-TeCA Concentration	Tetrachloroethene Concentration	Chlorobenzene Concentration	Carbon Tetrachloride Concentration
RSP-0830	Groundwater from spring (µg/L)	12-Nov-13	1 U	1 U	1 U	1 U	1 U
RSP-0830	Surface water at spring (µg/L)	29-May-13	2.55	1 UJ	1 U	1 U	0.31 J
RSP-0830x	Surface water downstream of spring (µg/L)	29-May-13	3.13	1 UJ	1 U	1 U	0.38 J
RSP-0830	Sediment at spring (mg/kg)	29-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-0830x	Sediment downstream of spring (mg/kg)	29-May-13	0.01 UN	0.01 U	0.01 U	0.01 U	0.01 U
RSP-1070a	Groundwater from spring (µg/L)	24-Mar-09	12	8.2	0.43 J	1 U	1 U
RSP-1070a	Surface water at spring (µg/L)	24-Mar-09	13	1 U	0.6 J	1 U	0.26 J
RSP-1070axx	Surface water downstream of spring (µg/L)	24-Mar-09	12	1 U	0.53 J	1 U	0.24 J
RSP-1070a	Sediment at spring (mg/kg)	24-Mar-09	0.0047 j	0.003 j	0.0082 U	0.0082 U	0.0082 U
RSP-1070axx	Sediment downstream of spring (mg/kg)	24-Mar-09	0.0082 U	0.0082 U	0.0082 U	0.0082 U	0.0082 U
RSP-1086a	Groundwater from spring (µg/L)	2-Mar-14	8.56	6.82	0.42 J	1 U	1 J
RSP-1086a	Surface water at spring (µg/L)	28-Feb-14	6.36	5.25	0.35 J	1 U	1 U
RSP-1086ax	Surface water downstream of spring (µg/L)	2-Mar-14	6.22	5.33	0.3 J	1 U	1 U
RSP-1086a	Sediment at spring (mg/kg)	2-Mar-14	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-1086ax	Sediment downstream of spring (mg/kg)	2-Mar-14	0.00723 U	0.00723 U	0.00723 U	0.00723 U	0.00723 U
RSP-1126	Groundwater from spring (µg/L)	27-Feb-14	7.48	10.6	0.4 J	1 U	0.28 J
RSP-1126	Surface water at spring (µg/L)	27-Feb-14	10.2	10	0.59 J	1 U	0.41 J
RSP-1126x	Surface water downstream of spring (µg/L)	27-Feb-14	9.78	10.5	0.6 J	1 U	0.4 J
RSP-1126	Sediment at spring (mg/kg)	27-Feb-14	0.00643 U	0.00643 U	0.00643 U	0.00643 U	0.00643 U
RSP-1126x	Sediment downstream of spring (mg/kg)	27-Feb-14	0.00662 U	0.00177 J	0.00662 U	0.00662 U	0.00662 U
RSP-1160	Groundwater from spring (µg/L)	19-Mar-09	5.6	2.8	0.27 J	1 U	0.17 J
RSP-1160	Surface water at spring (µg/L)	19-Mar-09	8.3	4.3	0.35 J	1 U	0.23 J
RSP-1160xx	Surface water downstream of spring (µg/L)	19-Mar-09	4.8	2.7	0.2 J	1 U	0.15 J
RSP-1160	Sediment at spring (mg/kg)	19-Mar-09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-1160xx	Sediment downstream of spring (mg/kg)	21-Mar-09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-1174	Groundwater from spring (µg/L)	14-Jun-13	1 U	1 U	1 U	1 U	1 U
RSP-1174	Surface water at spring (µg/L)	14-Jun-13	1 U	1 U	1 U	1 U	1 U
RSP-1174x	Surface water downstream of spring (µg/L)	14-Jun-13	1 U	1 U	1 U	1 U	1 U
RSP-1174	Sediment at spring (mg/kg)	14-Jun-13	0.00583 U	0.00583 U	0.00583 UX	0.00583 U	0.00583 U
RSP-1174x	Sediment downstream of spring (mg/kg)	14-Jun-13	0.00719 U	0.00719 U	0.00719 UX	0.00719 U	0.00719 U

Table 6-3a

**Analytical Results of VOCs for Collocated Groundwater, Spring, Surface Water, and Sediment Samples  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 3 of 3)

Sample Location	Sample Type and Location	Sample Date	TCE Concentration	1,1,2,2-TeCA Concentration	Tetrachloroethene Concentration	Chlorobenzene Concentration	Carbon Tetrachloride Concentration
RSP-1212	Groundwater from spring (µg/L)	5-Mar-09	6	1.1	1.8	1 U	1 U
RSP-1212	Surface water at spring (µg/L)	5-Mar-09	5.6	1.2	1.6	1 U	1 U
RSP-1212x	Surface water downstream of spring (µg/L)	5-Mar-09	5.3	1.1	1.5	1 U	1 U
RSP-1212	Sediment at spring (mg/kg)	5-Mar-09	0.0034 J	0.01 U	0.0052 J	0.01 U	0.01 U
RSP-1212x	Sediment downstream of spring (mg/kg)	5-Mar-09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-1290	Groundwater from spring (µg/L)	17-Mar-09	2.4	2.1	0.15 J	1 U	1 U
RSP-1290	Surface water at spring (µg/L)	17-Mar-09	2.6	2.4	0.17 J	1 U	1 U
RSP-1290x	Surface water downstream of spring (µg/L)	17-Mar-09	2.2	2.2	1 U	1 U	1 U
RSP-1290	Sediment at spring (mg/kg)	17-Mar-09	0.0075 U	0.0075 U	0.0075 U	0.0075 U	0.0075 U
RSP-1324	Groundwater from spring (µg/L)	3-Mar-14	4.62	5.91	1 U	1 U	1 U
RSP-1324	Surface water at spring (µg/L)	3-Mar-14	6.43	7.29	0.38 J	1 U	1 U
RSP-1324x	Surface water downstream of spring (µg/L)	3-Mar-14	7.72	8.86	0.49 J	1 U	0.34 J
RSP-1324	Sediment at spring (mg/kg)	3-Mar-14	0.008 U	0.008 U	0.008 U	0.008 U	0.008 U
RSP-1424	Groundwater from spring (µg/L)	20-May-13	1 U	1 U	1 U	1 U	1 U
RSP-1424	Surface water at spring (µg/L)	20-May-13	1 U	1 U	1 U	1 U	1 U
RSP-1424x	Surface water downstream of spring (µg/L)	21-May-13	1 U	1 U	1 U	1 U	1 U
RSP-1424	Sediment at spring (mg/kg)	20-May-13	0.36 U	0.36 U	0.36 U	0.36 U	0.36 U
RSP-1424x	Sediment downstream of spring (mg/kg)	21-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
RSP-1506a	Groundwater from spring (µg/L)	19-Mar-09	2.3	1 U	2.2	1 U	0.24 J
RSP-1506a	Surface water at spring (µg/L)	19-Mar-09	2.3	1 U	2.2	1 U	0.26 J
RSP-1506ax	Surface water downstream of spring (µg/L)	19-Mar-09	2.3	1 U	2.1	1 U	0.19 J
RSP-1506a	Sediment at spring (mg/kg)	19-Mar-09	0.01 U	0.01 U	0.01 U	0.0054 J	0.01 U

U - The analyte was analyzed for but was not detected or the concentration of the analyte quantitated below the detection limit.

J - The reported result is estimated.

UJ - Not detected, estimated due to data validation anomaly.

UB - Potential false positive. These data do not factor into the decision-making process.

µg/L - Micrograms per liter.

mg/kg - milligrams per kilogram

TCE - Trichloroethene.

TeCA - Tetrachloroethane.

Table 6-3b

**Analytical Results of Pesticides for Collocated Groundwater, Spring, Surface Water, and Sediment Samples  
RSA-147/147/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 1)

Sample Location	Sample Type and Location	Sample Date	beta-BHC Concentration	alpha-BHC Concentration	Aldrin Concentration	Dieldrin Concentration	4,4'-DDD Concentration	4,4'-DDE Concentration	4,4'-DDT Concentration	Arsenic Concentration
RSP-0802	Groundwater from spring (µg/L)	5-Jun-13	0.01 J	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	NS
RSP-0802	Surface water at spring (µg/L)	5-Jun-13	0.00808 J	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	10 U
RSP-0802	Sediment at spring (mg/kg)	5-Jun-13	0.00117 UJ	0.0005 J	0.00117 U	0.0008 J	0.0023 J	0.00322 J	0.00117 UJ	8.18
RSP-0820	Groundwater from spring (µg/L)	18-Mar-09	0.009 U	0.009 U	0.009 U	0.01 U	0.01 J	0.01 J	0.01 U	NS
RSP-0820	Surface water at spring (µg/L)	18-Mar-13	0.0075 J	0.0093 U	0.0093 U	0.01 U	0.01 J	0.01 J	0.01 U	10 U
RSP-0820x	Surface water downstream of spring (µg/L)	18-Mar-13	0.0075 J	0.0092 U	0.0092 U	0.01 U	0.01 J	0.01 J	0.01 U	10 U
RSP-0824a	Groundwater from spring (µg/L)	18-Mar-09	0.01	0.009 U	0.009 U	0.01 U	0.01 J	0.01 J	0.01 U	NS
RSP-0824a	Surface water at spring (µg/L)	18-Mar-13	0.02	0.01 U	0.01 U	0.02 U	0.01 J	0.01 J	0.02 U	10 U
RSP-0824ax	Surface water downstream of spring	18-Mar-13	0.01 J	0.0092 U	0.0092 U	0.01 U	0.02 J	0.02 J	0.01 U	10 U
RSP-0830	Groundwater from spring (µg/L)	29-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 J	0.01 J	0.01 U	NS
RSP-0830	Surface water at spring (µg/L)	29-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.02 J	0.02 J	0.01 U	10 U
RSP-0830x	Surface water downstream of spring (µg/L)	29-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.02 J	0.02 J	0.01 U	10 U
RSP-0830	Sediment at spring (mg/kg)	29-May-13	0.00222 J	0.00128 U	0.000772 J	0.0006 J	0.15	0.11 J	0.33	NS
RSP-0830x	Sediment downstream of spring (mg/kg)	29-May-13	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.1 J	0.07 J	0.37 J	NS
RSP-1174	Groundwater from spring (µg/L)	14-Jun-13	0.00509 J	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	NS
RSP-1174	Surface water at spring (µg/L)	14-Jun-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	10 U
RSP-1174x	Surface water downstream of spring (µg/L)	14-Jun-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	10 U
RSP-1174	Sediment at spring (mg/kg)	14-Jun-13	0.000829 U	0.000829 U	0.000829 U	0.000829 U	0.000829 U	0.000829 U	0.000829 U	2.17 J
RSP-1174x	Sediment downstream of spring (mg/kg)	14-Jun-13	0.000812 U	0.000812 U	0.000812 U	0.000812 U	0.000812 U	0.000812 U	0.000812 U	3.99
RSP-1424	Groundwater from spring (µg/L)	20-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.00563 UB	NS
RSP-1424	Surface water at spring (µg/L)	20-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.00635 UB	10 U
RSP-1424x	Surface water downstream of spring (µg/L)	21-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.0083 UB	10 U
RSP-1424	Sediment at spring (mg/kg)	20-May-13	0.000852 U	0.000852 U	0.000852 U	0.000852 U	0.000852 U	0.000852 U	0.000852 U	4.10
RSP-1424x	Sediment downstream of spring (mg/kg)	21-May-13	0.00127 U	0.00127 U	0.00127 U	0.00127 U	0.00187 J	0.00414 J	0.00127 U	3.85
RSP-1501	Groundwater from spring (µg/L)	22-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 UB	NS
RSP-1501	Surface water at spring (µg/L)	22-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	10 U
RSP-1501	Sediment at spring (mg/kg)	22-May-13	0.0009 U	0.0009 U	0.0009 U	0.0009 U	0.0009 U	0.0009 U	0.0009 U	7.67
RSP-1504	Groundwater from spring (µg/L)	22-May-13	NA	NA	0.01 U	0.01 U	0.01 U	0.01 J	0.01 U	NS
RSP-1504	Surface water at spring (µg/L)	22-May-13	0.03	0.02	0.01 U	0.01 U	0.01 U	0.01 J	0.01 U	10.6
RSP-1504	Sediment at spring (mg/kg)	22-May-13	0.0009 U	0.0009 U	0.0009 U	0.0009 U	0.001 J	0.0025 J	0.0009 U	87.2
RSP-1506a	Groundwater from spring (µg/L)	19-Mar-09	0.07 J	0.04 J	0.0094 U	0.01 U	0.01 U	0.01 U	0.01 U	12.5
RSP-1506a	Surface water at spring (µg/L)	19-Mar-09	0.07 J	0.04 J	0.0092 U	0.01 U	0.01 U	0.01 U	0.01 U	11.2
RSP-1506ax	Surface water downstream of spring (µg/L)	19-Mar-09	0.07 J	0.04 J	0.0096 U	0.01 U	0.01 U	0.01 U	0.01 U	14.2
RSP-1506a	Sediment at spring (mg/kg)	19-Mar-09	0.00088 J	0.00048 J	0.0006 U	0.0013 U	0.0066 J	0.0076 J	0.0013 U	47.8
RSP-1506ax	Sediment downstream of spring (mg/kg)	19-Mar-09	NS	NS	NS	NS	NS	NS	NS	NS
RSP-1510a	Groundwater from spring (µg/L)	21-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.00789 UB	NS
RSP-1510a	Surface water at spring (µg/L)	21-May-13	0.01 U	0.01 U	0.01 U	0.01 U	0.00762 J	0.01 U	0.01 U	6.26
RSP-1510a	Sediment at spring (mg/kg)	21-May-13	0.0009 U	0.0009 U	0.0009 U	0.0009 U	0.0011	0.0014 J	0.0027 J	136

U - The analyte was analyzed for but was not detected or the concentration of the analyte quantitated below the DL.  
J - The reported result is estimated.  
UJ - Not detected, estimated due to data validation anomaly.  
UB - Potential false positive. These data do not factor into the decision making process.

µg/L - Micrograms per liter.  
mg/kg - Milligrams per kilogram.

**Table 7-1**

**Preliminary Screening Level Exceedances:  
Focus Area 1 Shallow Groundwater  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

Well Location	Zone	Fail	Pass	VOCs
				Trichloroethene
F56-RS049	OVB	X		x
F57-RS1389	OVB		X	
F57-RS1390	OVB		X	
F57-RS1391	OVB		X	
F57-RS140	INT		X	
F57-RS731	OVB	X		x
F57-RS732	OVB		X	
F57-RS733	OVB		X	
<b>Total Failing Wells</b>		<b>2</b>	<b>6</b>	<b>2</b>

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

INT - Interface well.

OVB - Overburden well.

PSL - Preliminary screening level.

PSV - Preliminary screening value.

VOC - Volatile organic compound.

x - Chemical was detected above its PSV in at least one sample collected from this well.

Table 7-2

**Preliminary Screening Level Exceedances:  
Focus Area 2 Shallow and Deep Groundwater  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 2)

Well Location	Zone	Fail	Pass	Metals		SVOCs					VOCs			
				Arsenic	Manganese	Benzo(a)anthracene	Benzo(a)pyrene	bis(2-Ethylhexyl)phthalate	Dibenz(a,h)anthracene	Naphthalene	1,1,2,2-Tetrachloroethane	Bromomethane	Tetrachloroethene	Trichloroethene
SHALLOW														
225-RS1900	OVB		X											
F122E-RS1266	OVB-S		X											
F122E-RS1267	OVB	X						x						
F122E-RS1268	OVB-S		X											
F122N-RS1263	OVB		X											
F122N-RS1264	OVB-S		X											
F122N-RS1265	OVB		X											
F122NW-RS1248	OVB	X		x										
F122NW-RS1249	OVB-S	X		x										
F122NW-RS1255	OVB	X								x		x		
F122NW-RS1256	OVB-S	X		x									x	
F122NW-RS1257	OVB		X											
F122NW-RS1258	OVB-S	X			x			x		x				
F122NW-RS1259	OVB	X		x										
F122NW-RS1260	OVB-S	X		x										
F122NW-RS1261	OVB	X									x			
F122NW-RS1262	OVB-S	X		x										
F122-RS048	OVB		X											
F122-RS050	OVB		X											
F122-RS1057	OVB-S	X		x									x	
F122-RS1059	OVB		X											
F122-RS1060	OVB-S		X											
F122-RS1062	OVB		X											
F122-RS509	OVB-S	X											x	
F122-RS510	OVB		X											
F122-RS511	OVB		X											
F122-RS512	OVB		X											
F122-RS514	BR	X											x	
F122-RS515	BR		X											
F122-RS631	OVB-S	X											x	
F122-RS949	OVB		X											
F122-RS950	OVB		X											
F122-RS953	BR		X											
F122S-RS1269	OVB-S		X											
F122S-RS1270	OVB-S		X											
F122S-RS1271	OVB-S		X											
F122S-RS1272	OVB-S		X											
F122S-RS1273	OVB		X											
F122S-RS1274	OVB-S		X											
F122S-RS1275	OVB		X											
F122S-RS1276	OVB-S		X											
F127-RS1321	OVB		X											
F127-RS1322	OVB		X											

Table 7-2

**Preliminary Screening Level Exceedances:  
Focus Area 2 Shallow and Deep Groundwater  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 2 of 2)

Well Location	Zone	Fail	Pass	Metals		SVOCs					VOCs			
				Arsenic	Manganese	Benzo(a)anthracene	Benzo(a)pyrene	bis(2-Ethylhexyl)phthalate	Dibenz(a,h)anthracene	Naphthalene	1,1,2,2-Tetrachloroethane	Bromomethane	Tetrachloroethene	Trichloroethene
F127-RS1323	OVB	X				x		x						
F127-RS1465	OVB	X				x		x	x					
F127-RS1466	OVB	X						x						
F127-RS1467	OVB		X											
F139-RS1027	OVB		X											
F139-RS521	OVB	X		x										
F139-RS524	BR		X											
F139-RS632	OVB-S	X		x										x
F139-RS912	OVB	X		x										
F139-RS913	BR		X											
F139-RS914	OVB		X											
F139-RS915	BR		X											
F56-RS051	INT		X											
F56-RS516	OVB		X											
F56-RS517	OVB	X						x						
F56-RS518	OVB		X											
F56-RS519	BR	X												x
F56-RS520	BR		X											
F56-RS630	OVB-S	X		x	x	x	x		x					
<b>DEEP</b>														
F122-RS513	BR-D		X											
<b>Total Failing Wells</b>		<b>23</b>	<b>40</b>	<b>11</b>	<b>2</b>	<b>3</b>	<b>1</b>	<b>6</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>7</b>

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

BR - Bedrock well.

BR-D - Deep bedrock well.

NA - Not applicable.

OVB - Overburden well.

OVB-S - Shallow overburden well.

PSL - Preliminary screening level.

PSV - Preliminary screening value.

SVOC - Semivolatile organic compound.

VOC - Volatile organic compound.

x - Chemical was detected above its PSV in at least one sample collected from this well.

**Table 7-3**

**Preliminary Screening Level Exceedances:  
Focus Area 3 Shallow Groundwater  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

Well Location	Zone	Fail	Pass	VOCs		
				1,1,2,2-Tetrachloroethane	Carbon tetrachloride	Trichloroethene
147-RS1972	OVB	X		x	x	x
F117-RS387	OVB-S		X			
F59-RS220	OVB		X			

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

OVB - Overburden well.

OVB-S - Shallow overburden well.

PSL - Preliminary screening level.

PSV - Preliminary screening value.

VOC - Volatile organic compound.

x - Chemical was detected above its PSV in at least one sample collected from this well.

Table 7-4

**Preliminary Screening Level Exceedances:  
Focus Area 4 Shallow and Deep Groundwater  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

Well Location	Zone	Fail	Pass	Metals	Explosives										Pesticides					VOCs									
				Manganese	1,3-Dinitrobenzene	2,4,6-Trinitrotoluene	2,4-Dinitrotoluene	2-Amino-4,6-dinitrotoluene	2-Nitrotoluene	3-Nitrotoluene	4-Amino-2,6-dinitrotoluene	Nitroglycerin	PETN	RDX	4,4'-DDD	4,4'-DDE	Aldrin	alpha-BHC	beta-BHC	Dieldrin	1,1,2,2-Tetrachloroethane	1,1-Dichloroethane	Acetone	Benzene	Chlorobenzene	Chloroform	Methylene chloride	Trichloroethene	Vinyl chloride
SHALLOW																													
053-RS1997	BR		X																										
053-RS1999	INT	X																								X	X		
053-RS2000	INT	X																			X	X		X	X	X	X		
053-RS2001	INT	X																						X	X		X		
053-RS2002	INT	X																											
053-RS2003	INT	X														X	X		X	X	X				X	X			
053-RS2004	INT	X																				X	X	X	X				
053-RS2175	BR	X					X	X			X	X		X			X					X	X	X	X				
053-RS2176	BR	X			X	X	X	X		X	X		X	X								X	X			X			
F10-RS087	OVB-S	X							X											X								X	
F10-RS231	BR	X							X									X		X							X		
F53-RS032	OVB-S		X																										
F53-RS191	OVB		X																										
F53-RS193	OVB	X																X					X						
F53-RS194	BR	X																					X						
F53-RS270	OVB	X																							X				
F53-RS275	BR		X																										
F53-RS346	OVB-S		X																										
F53-RS347	OVB		X																										
F53-RS359	BR	X		X					X								X		X	X				X					
F53-RS551	BR		X							X																			
F53-RS554	OVB-S	X							X									X			X								
DEEP																													
F53-RS357	BR-D		X																										
Total Failing Wells		15	8	1	1	1	2	2	4	1	2	1	1	2	1	2	1	1	6	2	2	2	1	4	11	7	7	4	1

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

BR - Bedrock well.

BR-D - Deep bedrock well.

INT - Interface well.

NA - Not applicable.

OVB - Overburden well.

OVB-S - Shallow overburden well.

PSV - Preliminary screening value.

VOC - Volatile organic compound.

x - Chemical was detected above its PSV in at least one sample collected from this well.



Table 7-5

**Preliminary Screening Level Exceedances:  
Focus Area 5 Shallow Groundwater  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

Well Location	Zone	Fail	Pass	Metals		Explosives	VOCs				
				Arsenic	Mercury		1,1-Dichloroethene	Carbon tetrachloride	Chloroform	Methylene chloride	Trichloroethene
148-RS1974	OVB	X									x
148-RS1975	OVB	X									x
148-RS2254	BR		X								
148-RS2511	INT		X								
148-RS2512	INT	X									x
148-RS2513	INT		X								
148-RS2514	INT	X									x
148-RS2515	INT	X									x
148-RS2516	INT	X									x
E-RS1076	OVB	X						x	x	x	
E-RS1077	OVB		X								
E-RS1079	OVB		X								
E-RS1080	OVB	X									x
E-RS1081	OVB	X					x				x
E-RS1082	OVB	X									x
E-RS1093	BR		X								
E-RS1096	BR		X								
E-RS1097	BR		X								
E-RS1098	BR		X								
E-RS1133	OVB		X								
E-RS1140	BR	X				x					
E-RS1362	OVB	X									x
E-RS1363	OVB	X		x	x						
E-RS1364	OVB		X								
E-RS1365	OVB		X								
E-RS1366	OVB	X						x			
E-RS1367	OVB	X						x	x		x
E-RS1368	OVB	X		x				x			
E-RS1369	OVB		X								
E-RS1370	OVB	X						x			
E-RS1371	OVB	X				x					
E-RS1372	OVB		X								
F122E-RS951	OVB		X								
F55-RS1067	OVB		X								
F-RS1135	OVB		X								
<b>Total Failing Wells</b>		<b>18</b>	<b>17</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>5</b>	<b>2</b>	<b>1</b>	<b>11</b>

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

BR - Bedrock well.

INT - Interface well.

NA - Not applicable.

OVB - Overburden well.

PSL - Preliminary screening level.

PSV - Preliminary screening value.

VOC - Volatile organic compound.

x - Chemical was detected above its PSV in at least one sample collected from this well.

**Table 7-6**

**Preliminary Screening Level Exceedances:  
Focus Area 6 Shallow Groundwater  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

Well Location	Zone	Fail	Pass	VOCs
				Trichloroethene
149-RS1986	OVb	X		x

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

OVb - Overburden well.

PSL - Preliminary screening level.

PSV - Preliminary screening value.

VOC - Volatile organic compound.

x - Chemical was detected above its PSV in at least one sample collected from this well.

Table 7-7

**Preliminary Screening Level Exceedances:  
Shallow Groundwater for Wells Outside of Focus Areas  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 2)

Well Location	Zone	Fail	Pass	SVOCs
				Benz(a)anthracene
RSP-1501	NA		X	
030-RS2711	OVB		X	
030-RS2796	OVB		X	
147-RS1969	OVB		X	
147-RS1971	OVB		X	
147-RS2848	OVB		X	
148-RS1973	OVB		X	
148-RS1977	OVB		X	
148-RS1979	OVB		X	
148-RS1985	INT		X	
216-RS2632	OVB		X	
216-RS2633	OVB		X	
216-RS2634	OVB		X	
216-RS2635	OVB		X	
216-RS2812	OVB		X	
216-RS2813	OVB		X	
225-RS2043	OVB		X	
225-RS2044	OVB-S		X	
225-RS2471	OVB-S		X	
249-RS2838	INT		X	
250-RS1922	OVB		X	
250-RS1923	OVB		X	
250-RS1924	OVB		X	
290-RS2304	OVB		X	
290-RS2832	OVB		X	
290-RS2833	OVB		X	
290-RS2834	OVB		X	
290-RS2835	OVB		X	
E-RS1070	OVB		X	
E-RS1071	OVB		X	
E-RS1084	OVB		X	
E-RS1086	BR		X	
E-RS1095	BR		X	
E-RS1134	OVB		X	
E-RS1139	BR		X	
F10-RS081	OVB		X	
F127-RS1464	OVB		X	
F139-RS522	OVB		X	
F139-RS523	BR		X	
F30-RS1288	OVB		X	
F30-RS1306	OVB		X	
F30-RS1307	OVB		X	
F30-RS1308	OVB		X	
F49-RS1589	OVB		X	
F49-RS1590	BR		X	
F49-RS1591	BR		X	
F49-RS1593	BR		X	
F49-RS1594	OVB		X	
F53-RS348	OVB-S		X	

Table 7-7

**Preliminary Screening Level Exceedances:  
Shallow Groundwater for Wells Outside of Focus Areas  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 2 of 2)

Well Location	Zone	Fail	Pass	SVOCs
				Benzo(a)anthracene
F53-RS349	OVB		X	
F54-RS299	OVB		X	
F54-RS305	OVB		X	
F55-RS1065	OVB		X	
F55-RS1066	OVB-S		X	
F55-RS312	OVB		X	
F57-RS141	OVB		X	
F59-RS222	OVB		X	
FF-RS1447	OVB		X	
H52-RS752	OVB		X	
H52-RS753	OVB		X	
H61-RS137	OVB		X	
H62-RS045	OVB	X		x
MC-MW00-405	OVB		X	
MC-MW00-506	OVB		X	
MC-MW-030	OVB		X	
MC-MWBK-002	OVB		X	
MC-MWBK-013D	BR		X	
S63-RS123	OVB		X	
S63-RS124	OVB		X	
S63-RS125	OVB		X	
S63-RS126	OVB		X	
T-RS1055	BR		X	
T-RS1129	OVB		X	
T-RS1130	OVB		X	
Z-RS1230I	BR		X	
Z-RS1230S	INT		X	
Z-RS1235I	BR		X	
Z-RS1235S	BR		X	
<b>Total Failing Wells</b>		<b>1</b>	<b>77</b>	<b>1</b>

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

BR - Bedrock well.

INT - Interface well.

NA - Not applicable.

OVB - Overburden well.

OVB-S - Shallow overburden well.

PSV - Preliminary screening value.

SVOC - Semivolatile organic compound.

x - Chemical was detected above its PSV in at least one sample collected from this well.

**Table 7-8**

**Preliminary Screening Level Exceedances:  
Deep Groundwater for Wells Outside of Focus Areas  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

<b>Well Location</b>	<b>Zone</b>	<b>Fail</b>	<b>Pass</b>
E-RS1099	BR-D		X
F54-RS300	BR-D		X
T-RS1144	BR-D		X
Z-RS1230D	BR-D		X
Z-RS1235D	BR-D		X
<b>Total Failing Wells</b>		<b>0</b>	<b>5</b>

Fail - One or more chemical concentrations detected in samples collected from this well exceeded their PSVs.

Pass - No chemical concentrations from this well exceed their respective PSVs.

BR-D - Deep bedrock well.

PSV - Preliminary screening value.

x - Chemical was detected above its PSV in at least one sample collected from this well.

Table 7-9

**Summary of the Focus Area Evaluations  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 1 of 2)

	Shallow Groundwater	Chemicals Exceeding PSVs	Deep Groundwater	Chemicals Exceeding PSVs	Vapor Intrusion	VOCs Posing a Health Threat
FA-1	X	Trichloroethene	NA	NA	✓	(None)
FA-2	X	Arsenic Manganese Benzo(a)anthracene Benzo(a)pyrene bis(2-Ethylhexyl)phthalate Dibenz(a,h)anthracene Naphthalene 1,1,2,2-Tetrachloroethane Bromomethane Tetrachloroethene Trichloroethene	✓	(None)	✓	(None)
FA-3	X	1,1,2,2-Tetrachloroethane Carbon tetrachloride Trichloroethene	NA	NA	✓	(None)
FA-4	X	Manganese 1,3-Dinitrobenzene 2,4,6-Trinitrotoluene 2,4-Dinitrotoluene 2-Amino-4,6-dinitrotoluene 2-Nitrotoluene 3-Nitrotoluene 4-Amino-2,6-dinitrotoluene Nitroglycerin PETN RDX 4,4'-DDD 4,4'-DDE Aldrin alpha-BHC beta-BHC Dieldrin 1,1,2,2-Tetrachloroethane 1,1-Dichloroethane Acetone Benzene Chlorobenzene Chloroform Methylene chloride Trichloroethene Vinyl chloride	✓	(None)	✓	(None)

Table 7-9

**Summary of the Focus Area Evaluations  
RSA-147/148/149  
Redstone Arsenal, Madison County, Alabama**

(Page 2 of 2)

	Shallow Groundwater	Chemicals Exceeding PSVs	Deep Groundwater	Chemicals Exceeding PSVs	Vapor Intrusion	VOCs Posing a Health Threat
<b>FA-5</b>	<b>X</b>	Arsenic Mercury Nitrobenzene 1,1-Dichloroethene Carbon tetrachloride Chloroform Methylene chloride Trichloroethene	NA	NA	√	(None)
<b>FA-6</b>	<b>X</b>	Trichloroethene	NA	NA	√	(None)
<b>Outside Focus Areas</b>	<b>X</b>	Benzo(a)anthracene	√	(None)	√	(None)

Notes:

- √ No chemicals were identified as exceeding screening criteria.
- X Chemicals were identified as exceeding screening criteria.
- FA - Focus Area.
- NA - Not applicable.
- PSV - Preliminary screening value.

Table 7-10

**Conclusions of the ARBCA Evaluation for Exposure to Surface Water**  
**RSA-147/148/149**  
**Redstone Arsenal, Madison County, Alabama**

Receptors	Exposure to Surface Water <sup>a</sup>	Relevant COCs in Surface Water
<b>Indian Creek</b>		
Recreationist (Swimming Scenario)	√	(None)
Sportsman (Wading Scenario)	√	(None)
Sportsman (Fish Consumption Scenario)	X	4,4'-DDD 4,4'-DDE 4,4'-DDT alpha-Chlordane Dieldrin gamma-Chlordane Heptachlor Heptachlor epoxide
<b>Huntsville Spring Branch</b>		
Recreationist (Swimming Scenario)	√	(None)
Sportsman (Wading Scenario)	√	(None)
Sportsman (Fish Consumption Scenario)	X	4,4'-DDD 4,4'-DDE 4,4'-DDT alpha-BHC alpha-Chlordane beta-BHC Dieldrin gamma-Chlordane Heptachlor Heptachlor epoxide
<b>RSA-122 Stream</b>		
Recreationist (Wading Scenario)	√	(None)

## Notes:

- √ Denotes no COCs were identified or cumulative cancer risk and noncancer hazard were found to be acceptable in the RM-2 evaluation.
- X Cumulative cancer risk and/or noncancer hazard were found to be unacceptable.
- <sup>a</sup> Risk conclusions exclude inorganics found to be naturally occurring.  
COC - Chemical of concern.  
RM-2 - Risk-Management-2.



Table 7-11

**Screening-Level Ecological Risk Assessment Summary**  
**RSA-147/148/149**  
**Redstones Arsenal, Madison County, Alabama**

(Page 1 of 4)

Preliminary COPECs in the RSA-147/148/149 Subareas	HQ <sub>screen</sub>	SLERA Conclusion	Rationale
<b>INDIAN CREEK SUBAREA :</b>			
<b>Surface Water -</b>			
Aluminum	45	✓	Naturally occurring, MDC less than BSV
Cadmium	4.1	✓	Naturally occurring, Site-to-Background Comparison
Chromium	10	X	1 sample concentration is anomalously high
Iron	4.9	✓	Naturally occurring, MDC less than BSV
Lead	4.2	✓	Naturally occurring, Site-to-Background Comparison
Manganese	3.7	✓	Naturally occurring, MDC less than BSV
Nickel	1.4	X	1 sample concentration is anomalously high
Thallium	1.4	✓	Naturally occurring; Not site related
Perchlorate	NC	✓	HQs less than 1 based on alternate ESVs
4,4'-DDD	2	X	1 sample concentration exceeded the ESV
4,4'-DDT	22	X	1 sample concentration exceeded the ESV
alpha-Chlordane	3.3	X	2 sample concentrations exceed the ESV
Dieldrin	12	X	3 sample concentrations exceed the ESV
Endrin	4.3	X	1 sample concentration exceeded the ESV
Endrin Ketone	2.8	X	1 sample concentration exceeded the ESV
gamma-Chlordane	4.7	X	2 sample concentrations exceed the ESV
Heptachlor Epoxide	2.6	X	1 sample concentration exceeded the ESV
Freon-113	NC	+	Potential for ecological hazards unlikely, but uncertain
Trichloroethene	2.3	X	3 sample concentrations exceed the ESV
<b>Spring Throat Groundwater -</b>			
Aluminum	NC	✓	Naturally occurring, MDC less than BSV
Barium	NC	✓	Naturally occurring, MDC less than BSV
Calcium	NC	✓	Naturally occurring, MDC less than BSV
Chromium	348	✓	Naturally occurring, MDC less than BSV
Iron	NC	✓	Naturally occurring, MDC less than BSV
Magnesium	NC	✓	Naturally occurring, MDC less than BSV
Manganese	NC	✓	Naturally occurring, MDC less than BSV
Potassium	NC	✓	Naturally occurring, MDC less than BSV
Sodium	NC	✓	Naturally occurring, MDC less than BSV
Vanadium	NC	✓	Naturally occurring, MDC less than BSV
Perchlorate	NC	+	Potential for ecological hazards unlikely, but uncertain
2-Amino-4,6-dinitrotoluene	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
4,4'-DDE	542	X	Elevated HQ screen and detected in empirical sediment data
4,4'-DDT	1084	X	Elevated HQ screen and detected in empirical sediment data
alpha-Chlordane	24	X	Elevated HQ screen and detected in empirical sediment data
Dieldrin	5	X	Elevated HQ screen and detected in empirical sediment data

Table 7-11

**Screening-Level Ecological Risk Assessment Summary**  
**RSA-147/148/149**  
**Redstones Arsenal, Madison County, Alabama**

(Page 2 of 4)

<b>Preliminary COPECs in the RSA-147/148/149 Subareas</b>	<b>HQ<sub>screen</sub></b>	<b>SLERA Conclusion</b>	<b>Rationale</b>
gamma-Chlordane	16	X	Elevated HQ screen and detected in empirical sediment data
Chloromethane	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
Freon-113	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
Trichloroethene	5.6	X	Elevated HQ screen and detected in empirical sediment data
<b>HUNTSVILLE SPRING BRANCH SUBAREA :</b>			
<b>Surface Water -</b>			
Aluminum	232	✓	Naturally occurring, Site-to-Background Comparison
Barium	1	✓	Naturally occurring, Site-to-Background Comparison
Cadmium	4.5	✓	Naturally occurring, Site-to-Background Comparison
Chromium	3.9	✓	Naturally occurring, Site-to-Background Comparison
Copper	2.3	✓	Naturally occurring, Site-to-Background Comparison
Iron	32	✓	Naturally occurring, Site-to-Background Comparison
Lead	14	✓	Naturally occurring, Site-to-Background Comparison
Manganese	66	✓	Naturally occurring, Site-to-Background Comparison
Silver	106	✓	Naturally occurring, Site-to-Background Comparison
Vanadium	4.7	✓	Naturally occurring; Not site related.
Zinc	1.2	✓	Naturally occurring, Site-to-Background Comparison
Perchlorate	NC	✓	HQs less than 1 based on alternate ESVs
Tetryl	NC	✓	Low frequency of detection; therefore, ecological hazard not likely
4,4'-DDD	14	X	12 sample concentrations exceed the ESV
4,4'-DDT	320	X	3 sample concentrations exceed the ESV
alpha-Chlordane	3	X	10 sample concentrations exceed the ESV
Dieldrin	5.3	X	4 sample concentrations exceed the ESV
Endrin	6.3	✓	Low frequency of detection; therefore, ecological hazard not likely
Endrin Aldehyde	10	✓	Low frequency of detection; therefore, ecological hazard not likely
gamma-Chlordane	19	X	7 sample concentrations exceed the ESV
Heptachlor	1.8	✓	Low frequency of detection; therefore, ecological hazard not likely
Heptachlor Epoxide	9.2	X	5 sample concentrations exceed the ESV
Chloroethane	NC	✓	Low frequency of detection; therefore, ecological hazard not likely
Trichloroethene	6.2	X	5 sample concentrations exceed the ESV
<b>Spring Throat Groundwater -</b>			
Aluminum	NC	✓	Naturally occurring, MDC less than BSV
Barium	NC	✓	Naturally occurring, MDC less than BSV
Calcium	NC	✓	Naturally occurring, MDC less than BSV

Table 7-11

**Screening-Level Ecological Risk Assessment Summary**  
**RSA-147/148/149**  
**Redstones Arsenal, Madison County, Alabama**

(Page 3 of 4)

Preliminary COPECs in the RSA-147/148/149 Subareas	HQ <sub>screen</sub>	SLERA Conclusion	Rationale
Chromium	554	✓	Naturally occurring, Site-to-Background Comparison
Copper	5	✓	Naturally occurring, MDC less than BSV
Iron	NC	+	Potential for ecological hazards unlikely, but uncertain
Magnesium	NC	✓	Naturally occurring, MDC less than BSV
Manganese	NC	✓	Naturally occurring, MDC less than BSV
Potassium	NC	✓	Naturally occurring, MDC less than BSV
Sodium	NC	✓	Naturally occurring, MDC less than BSV
Vanadium	NC	✓	Naturally occurring, MDC less than BSV
Perchlorate	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
2-Amino-4,6-dinitrotoluene	NC	✓	Low frequency of detection; therefore, ecological hazard not likely
Nitroglycerin	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
4,4'-DDD	4121	X	Elevated HQ screen and detected in empirical sediment data
4,4'-DDE	11920	X	Elevated HQ screen and detected in empirical sediment data
4,4'-DDT	31879	X	Elevated HQ screen and detected in empirical sediment data
alpha-Chlordane	41	X	Elevated HQ screen and detected in empirical sediment data
Dieldrin	3	✓	Low frequency of detection; therefore, ecological hazard not likely
Endrin	1.5	✓	Low frequency of detection; therefore, ecological hazard not likely
gamma-Chlordane	69	X	Elevated HQ screen and detected in empirical sediment data
Heptachlor	842	✓	Low frequency of detection; therefore, ecological hazard not likely
Heptachlor Epoxide	37	X	Elevated HQ screen and detected in empirical sediment data
Carbazole	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
Chrysene	2.7	X	Elevated HQ screen and detected in empirical sediment data
Chloroethane	NC	✓	Low frequency of detection; therefore, ecological hazard not likely
Freon-113	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
Trichloroethene	17.8	X	Elevated HQ screen and detected in empirical sediment data
<b>RSA-122 STREAM SUBAREA :</b>			
<b>Surface Water -</b>			
Aluminum	2.1	✓	Naturally occurring, MDC less than BSV
Cadmium	1.5	✓	Naturally occurring, MDC less than BSV
Lead	1.1	✓	Naturally occurring, MDC less than BSV
Manganese	1.9	✓	Naturally occurring, MDC less than BSV
Perchlorate	NC	✓	HQs less than 1 based on alternate ESVs
Tetryl	NC	✓	HQs less than 1 based on alternate ESVs
4,4'-DDD	1.2	X	1 sample concentration exceeded the ESV
alpha-Chlordane	3.3	X	2 sample concentrations exceed the ESV
gamma-Chlordane	3.6	X	1 sample concentration exceeded the ESV
Trichlorofluoromethane	NC	+	Potential for ecological effects unlikely, but uncertain

Table 7-11

**Screening-Level Ecological Risk Assessment Summary**  
**RSA-147/148/149**  
**Redstones Arsenal, Madison County, Alabama**

(Page 4 of 4)

Preliminary COPECs in the RSA-147/148/149 Subareas	HQ <sub>screen</sub>	SLERA Conclusion	Rationale
<b>Spring Throat Groundwater :</b>			
Aluminum	NC	✓	Naturally occurring, MDC less than BSV
Barium	NC	✓	Naturally occurring, MDC less than BSV
Calcium	NC	✓	Naturally occurring, MDC less than BSV
Chromium	159	✓	Naturally occurring, MDC less than BSV
Iron	NC	✓	Naturally occurring, MDC less than BSV
Magnesium	NC	✓	Naturally occurring, MDC less than BSV
Manganese	NC	✓	Naturally occurring, Site-to-Background Comparison
Mercury	2	✓	Naturally occurring, MDC less than BSV
Sodium	NC	✓	Naturally occurring, MDC less than BSV
Vanadium	NC	✓	Naturally occurring, MDC less than BSV
Perchlorate	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
4,4'-DDE	704	X	Elevated HQ screen and detected in empirical sediment data
alpha-Chlordane	55	X	Elevated HQ screen and detected in empirical sediment data
gamma-Chlordane	11	X	Elevated HQ screen and detected in empirical sediment data
Heptachlor	522	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely
Trichlorofluoromethane	NC	✓	Partitioning to sediment is likely insignificant and ecological hazard not likely

X - Indicates that there is a potential for adverse impacts to surface water or sediment dwelling biota.

± - Indicates that the potential for adverse impacts to surface water or sediment is unlikely, but uncertain.

✓ - Indicates that adverse effects in surface water or sediment dwelling biota are unlikely to occur.

BSV - Background screening value.

COPEC - Chemical of potential ecological concern.

ESV - Ecological screening value.

HQ - Hazard quotient based on maximum detected concentration compared to ESV.

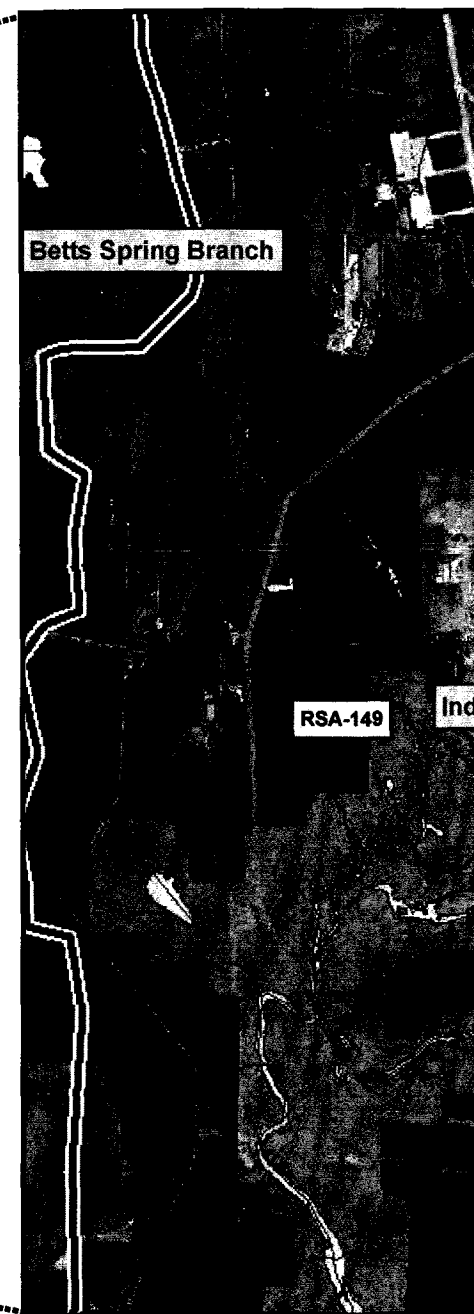
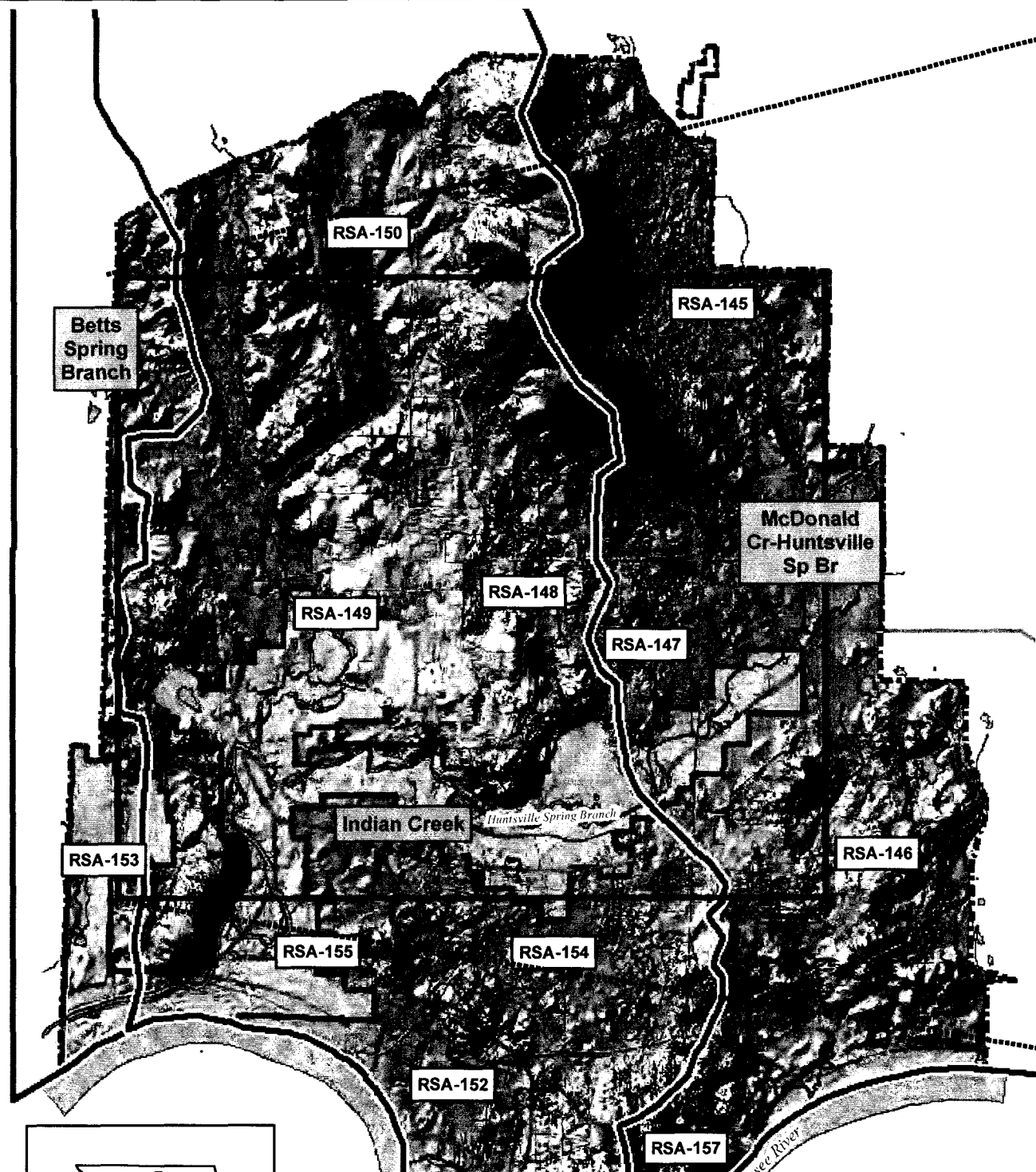
MDC - Maximum detected concentration.

NA - Not applicable.


NC - Not calculated due to the lack of a screening value and/or equilibrium partitioning coefficient.

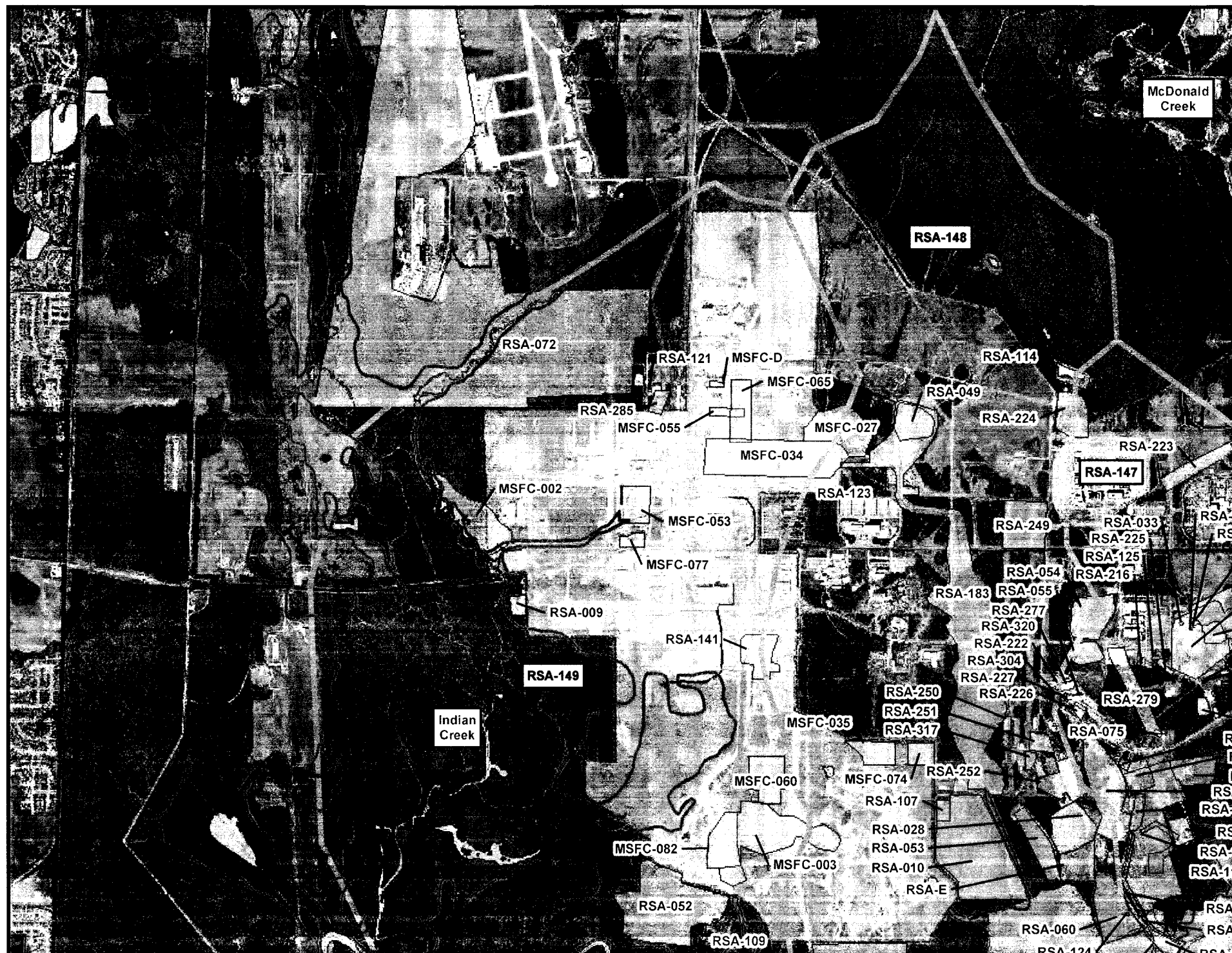
SLERA - Screening-level ecological risk assessment.

## FIGURES



**Legend**

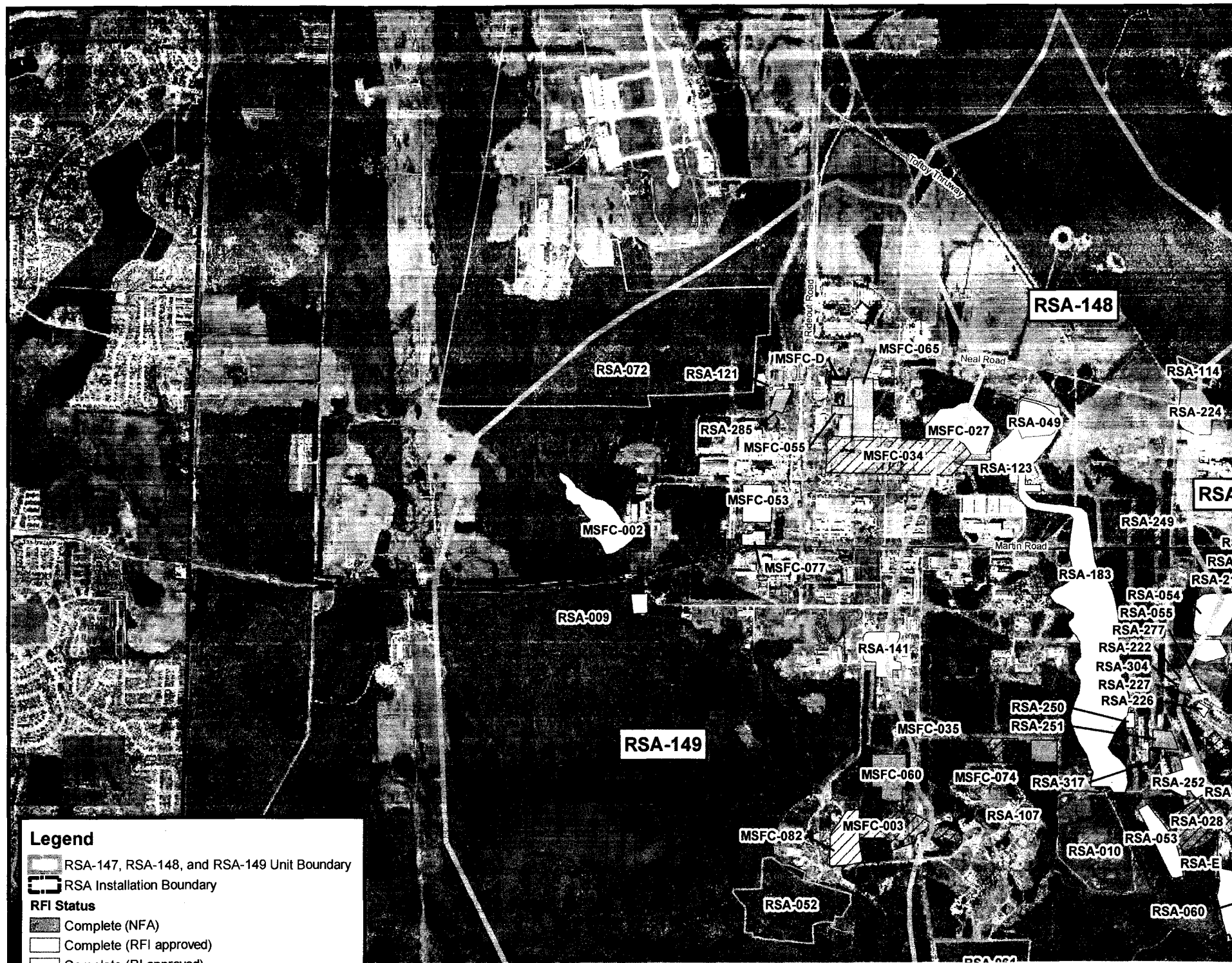
 RSA-147, RSA-148,

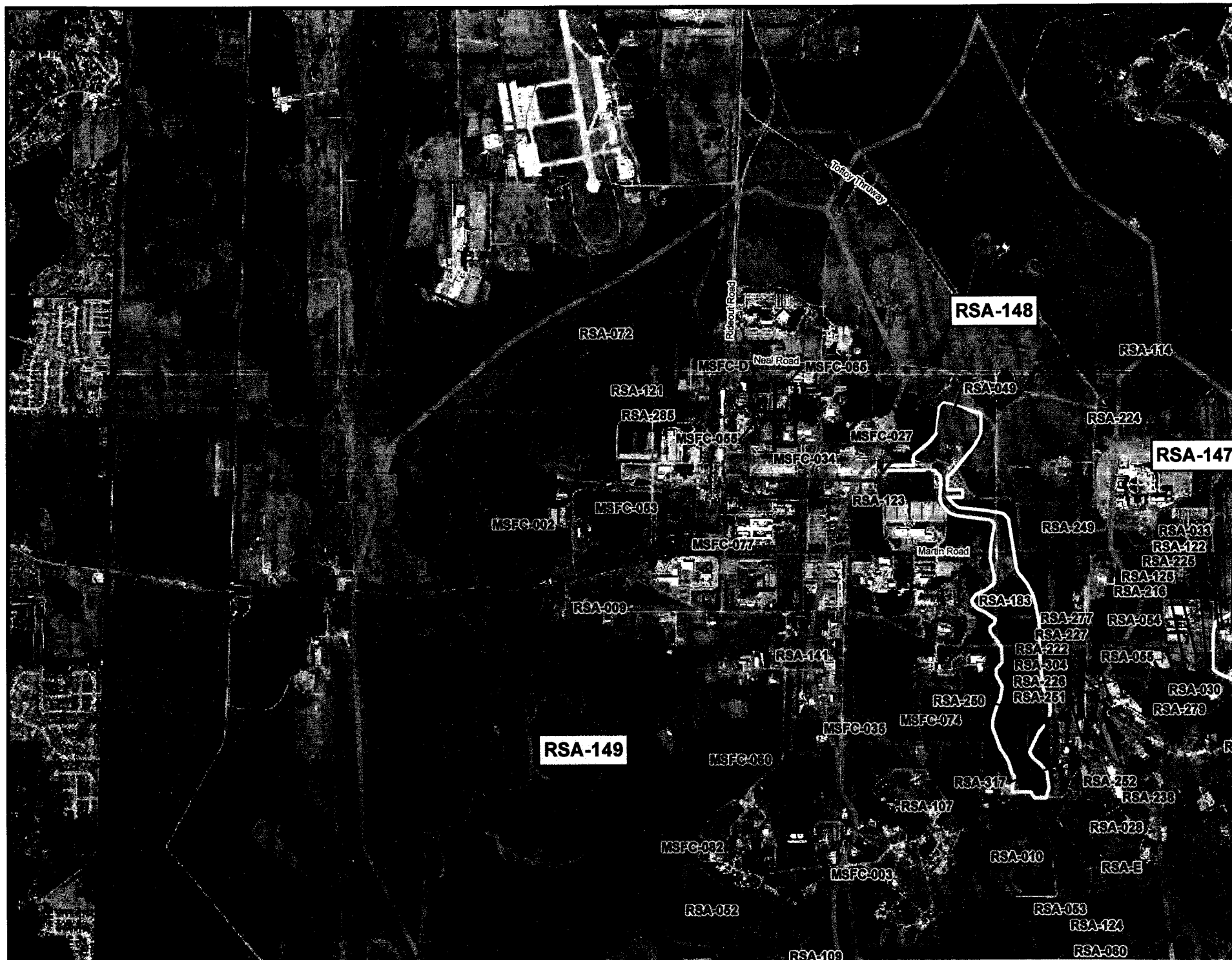


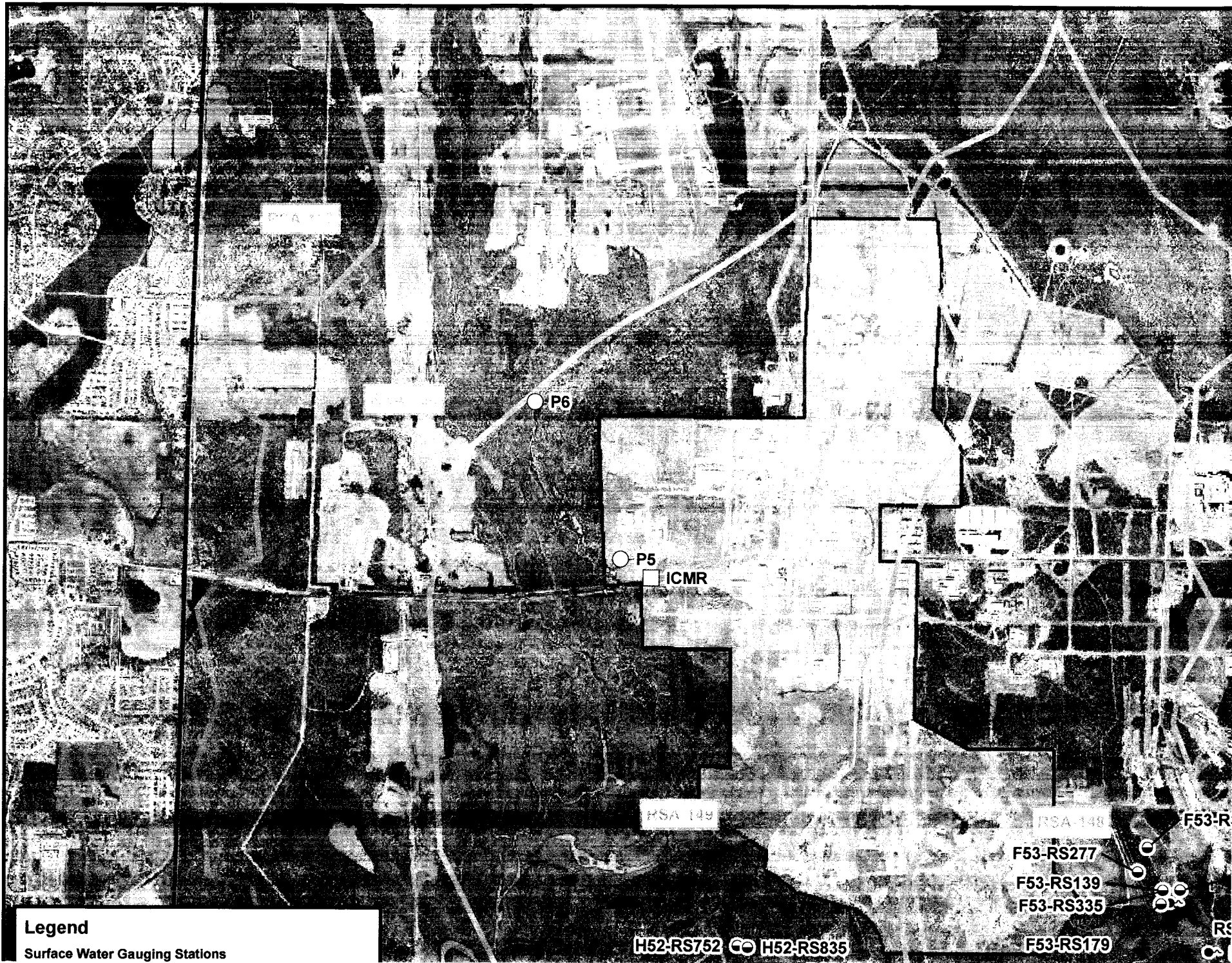












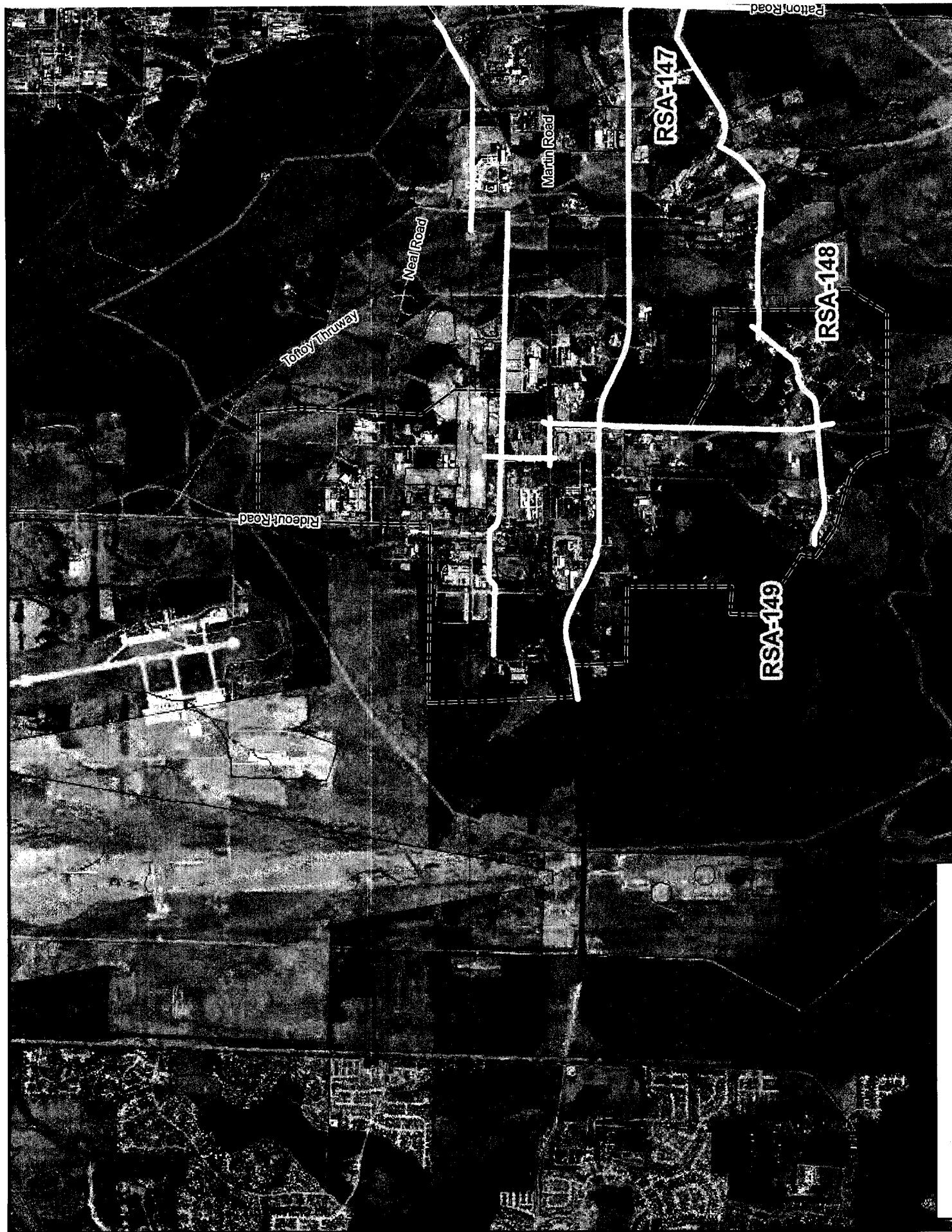
**Legend**

Surface Water Gauging Stations

H52-RS752 H52-RS835

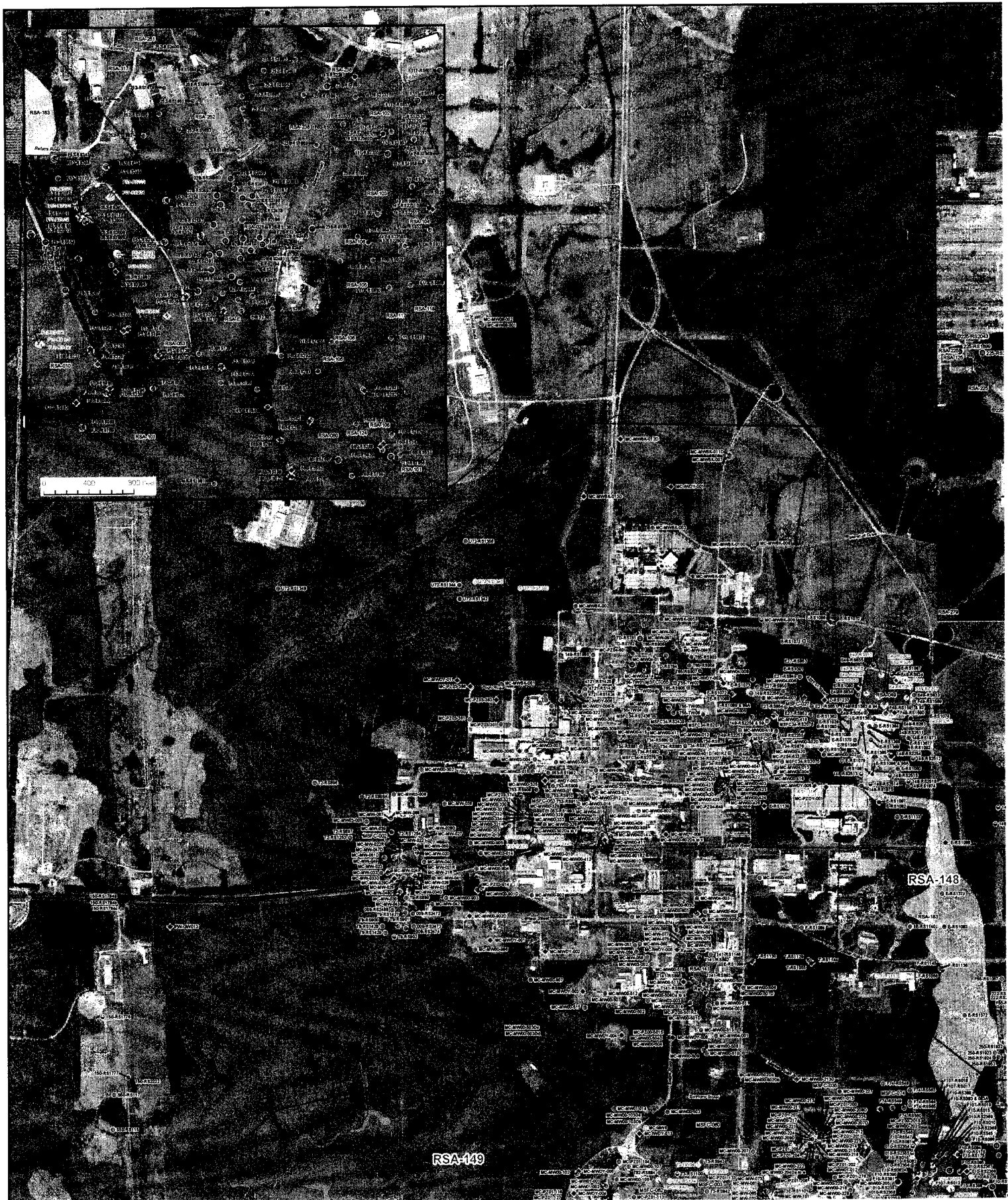
F53-RS179

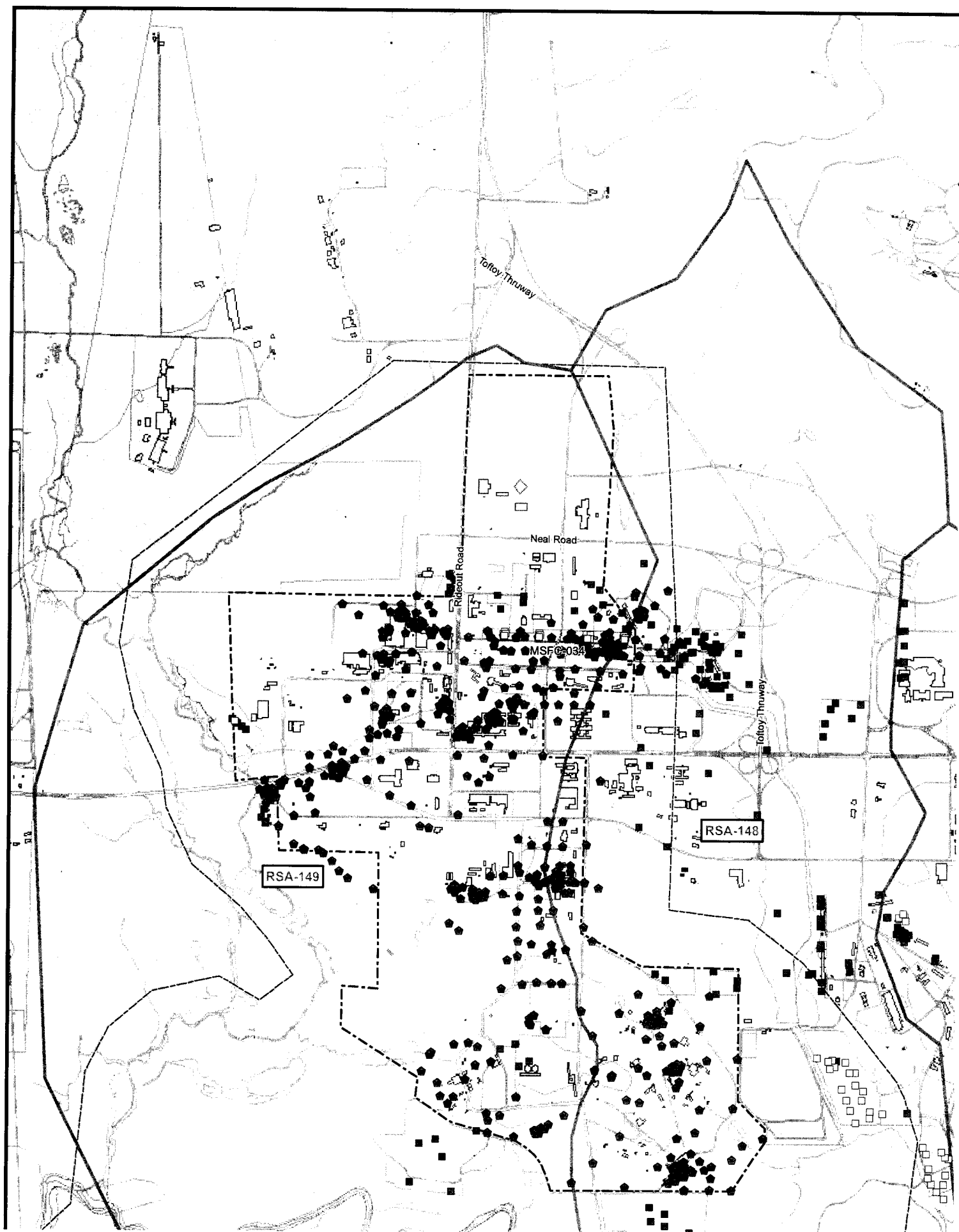










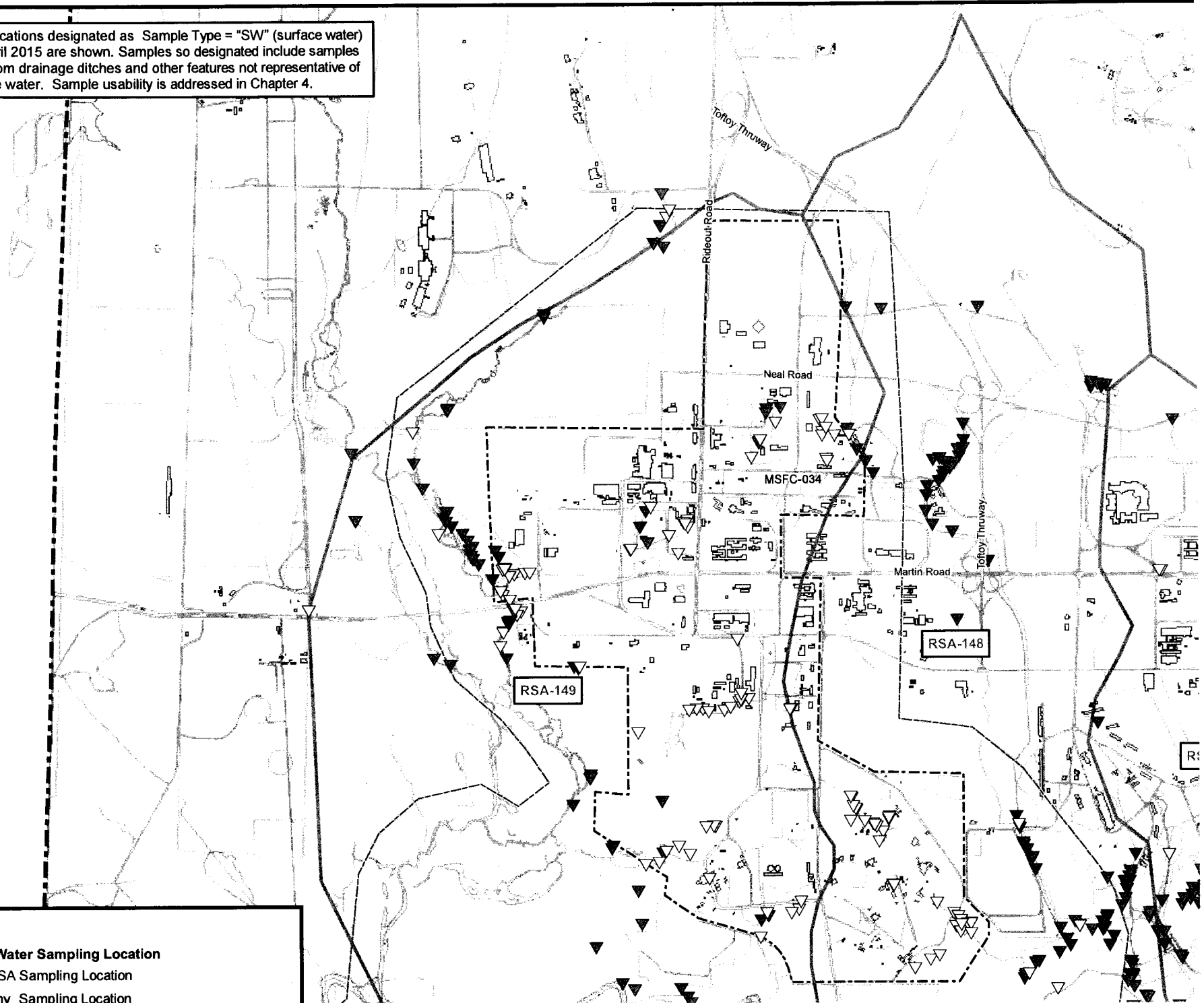


Note: All locations designated as Sample Type = "SW" (surface water) through April 2015 are shown. Samples so designated include samples collected from drainage ditches and other features not representative of true surface water. Sample usability is addressed in Chapter 4.

#### Legend

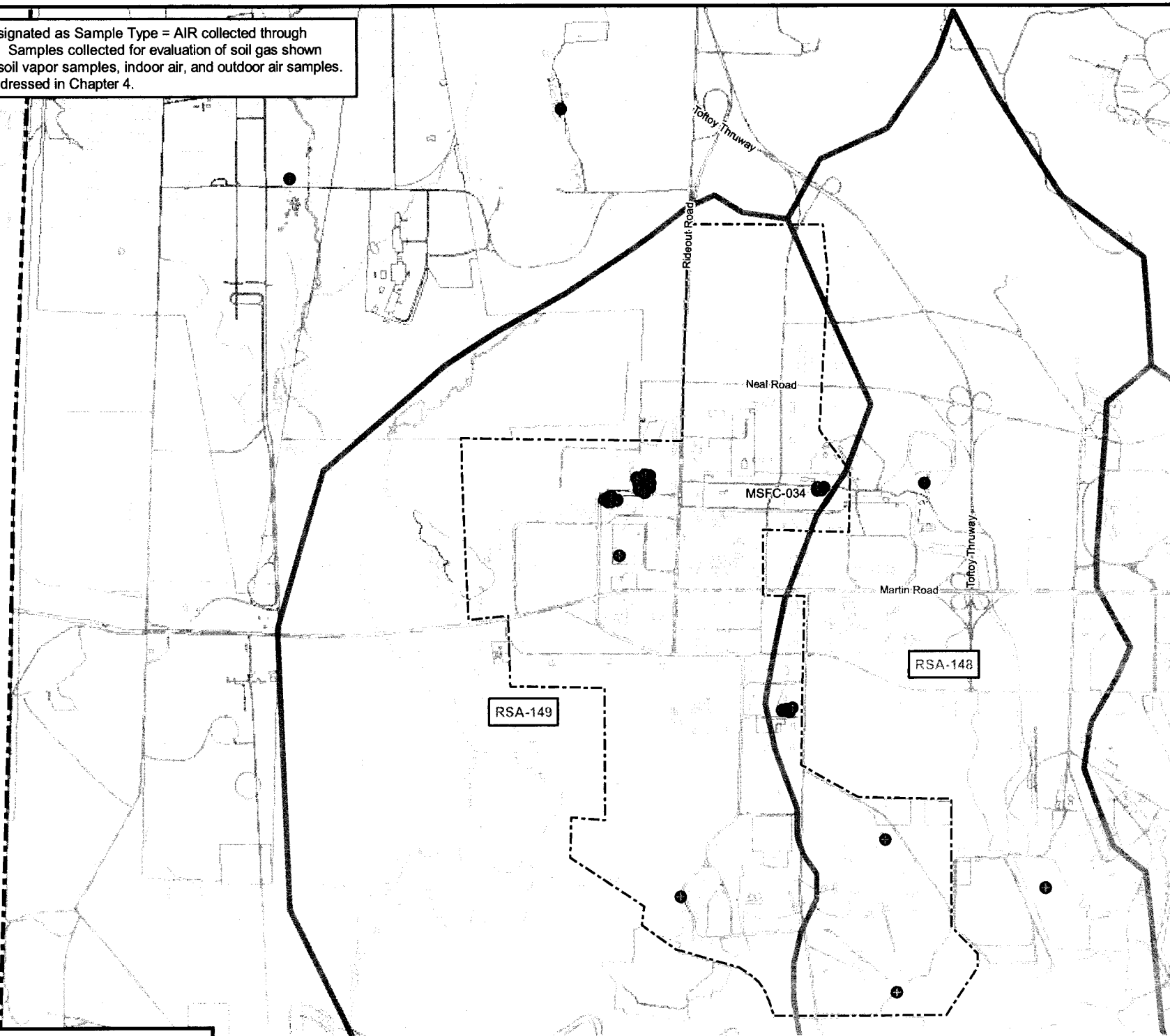
##### Surface Water Sampling Location

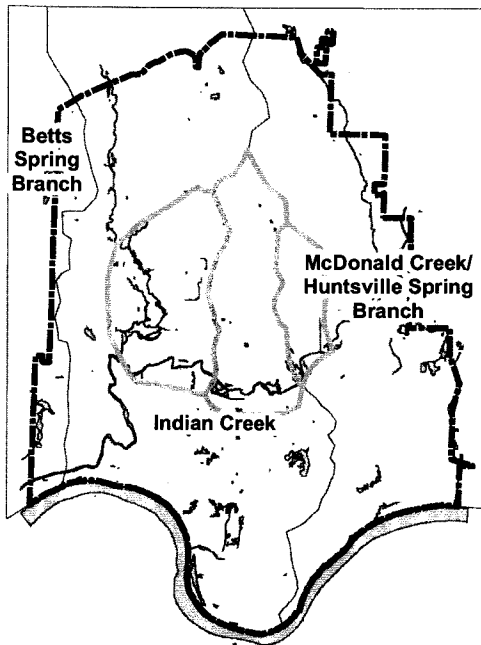
- ▽ NASA Sampling Location
- ▼ Army Sampling Location





Note: All samples designated as Sample Type = AIR collected through April 2013 are shown. Samples collected for evaluation of soil gas shown on this figure include soil vapor samples, indoor air, and outdoor air samples. Sample usability is addressed in Chapter 4.

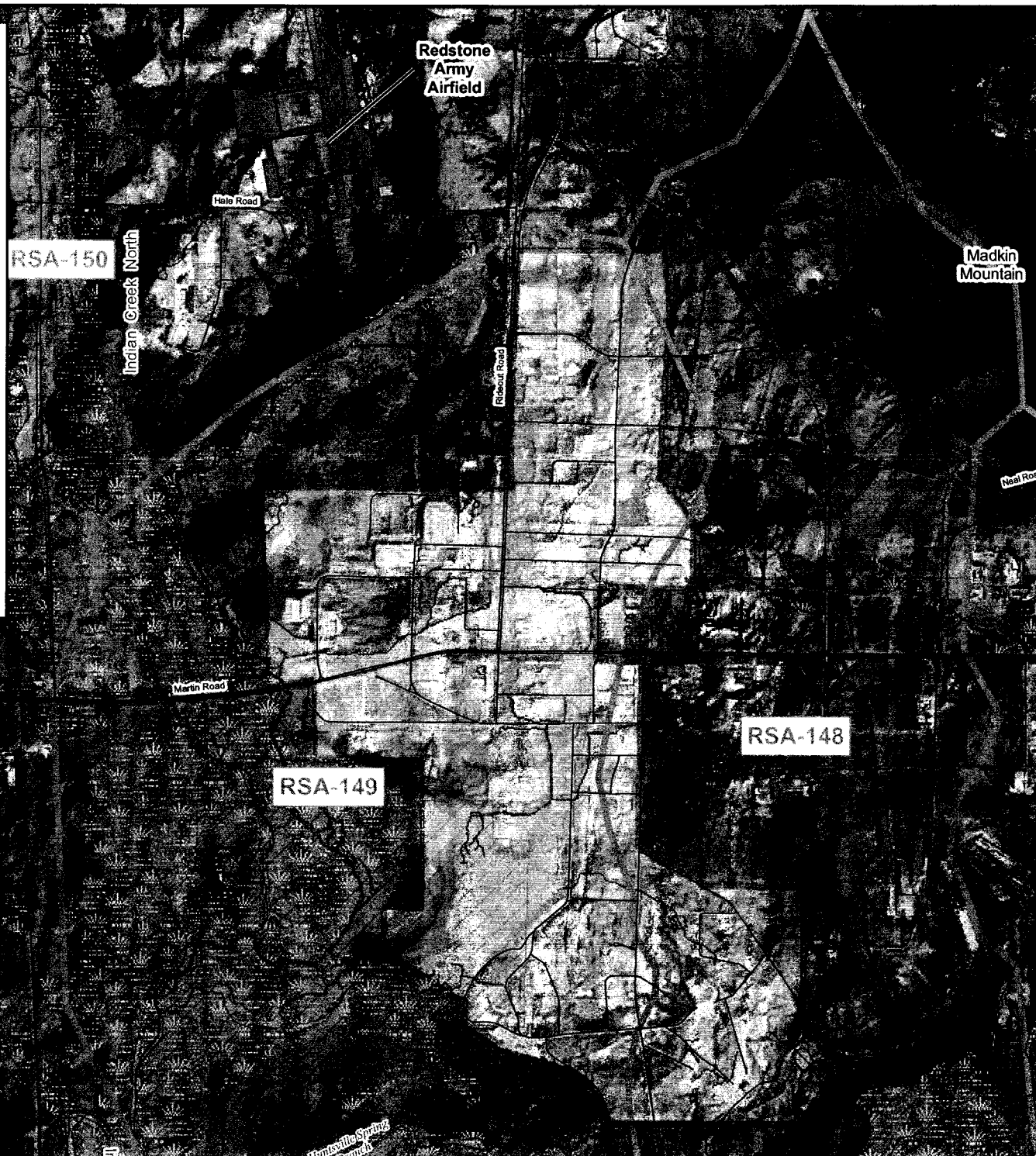


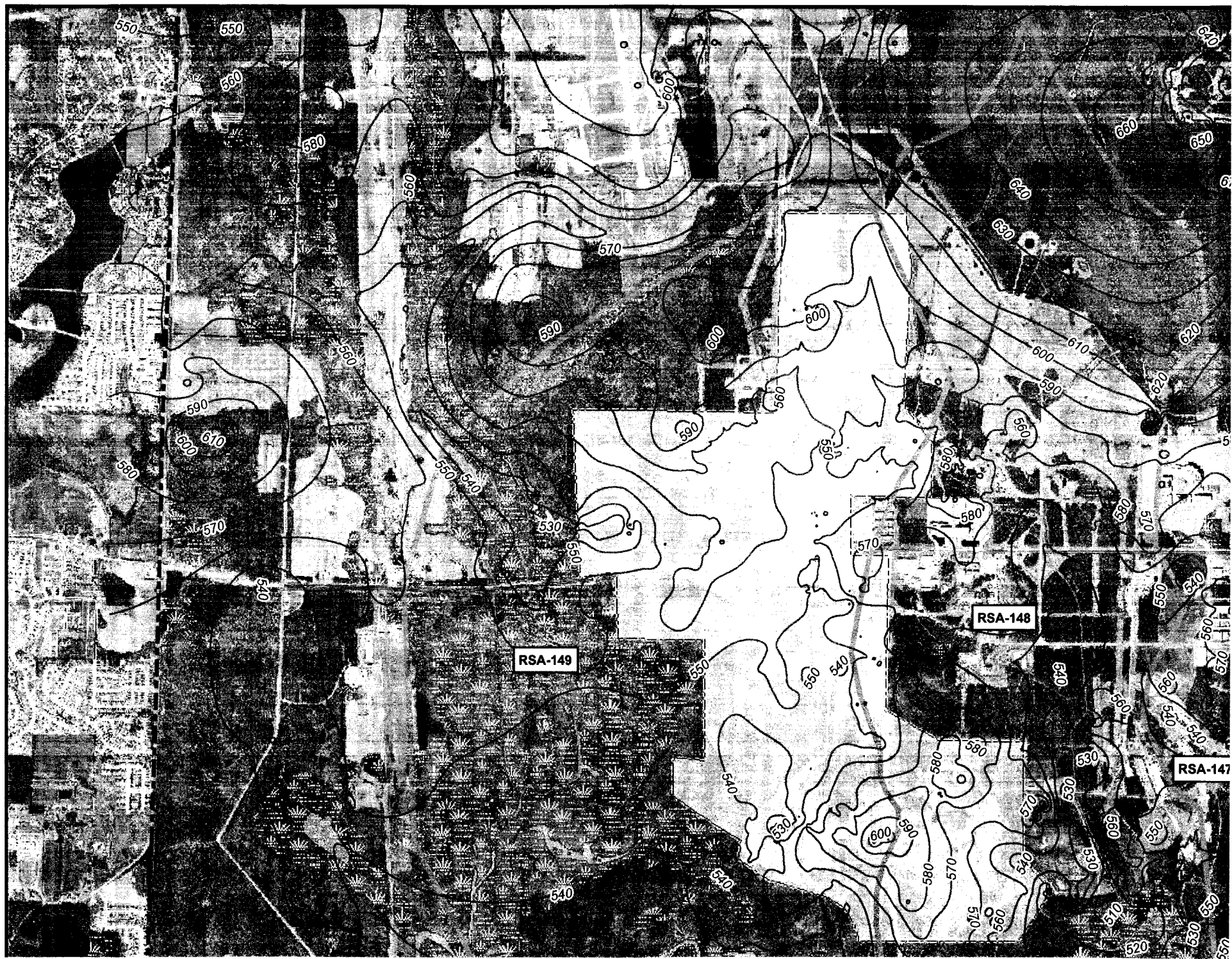


Area of Interest Within the Indian Creek Watershed

# Legend

- RSA Installation Boundary
- Groundwater Unit Boundary
- 100 year Floodplain





NSA-117

NSA-118

NSA-119

NSA-120

NSA-121

NSA-122

NSA-123

NSA-124

NSA-125

NSA-126

NSA-127

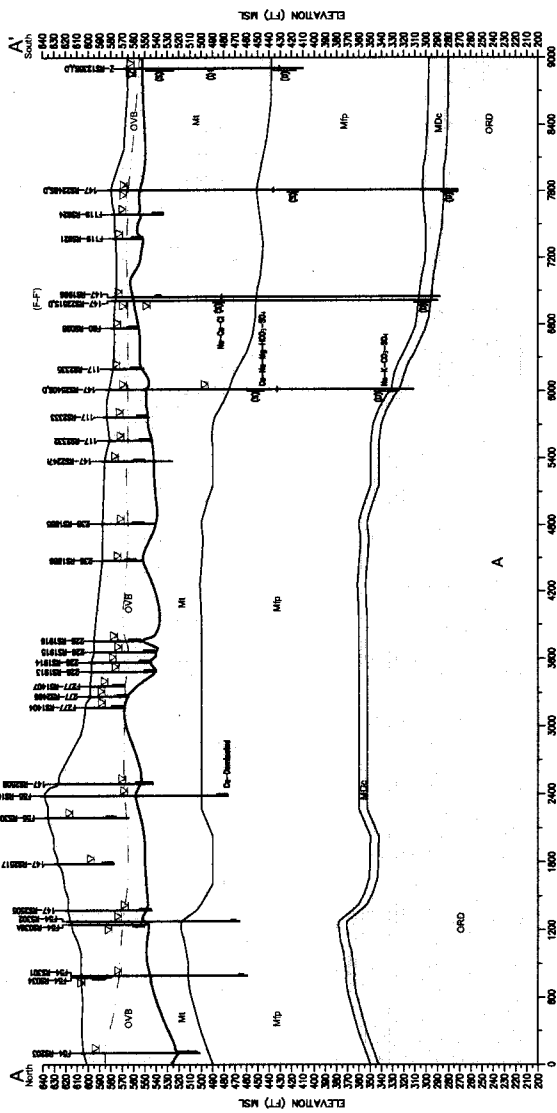
NSA-128

NSA-129

NSA-130

NSA-131

NSA-132



Cross-section A-A'

NSA-117

NSA-118

NSA-119

NSA-120

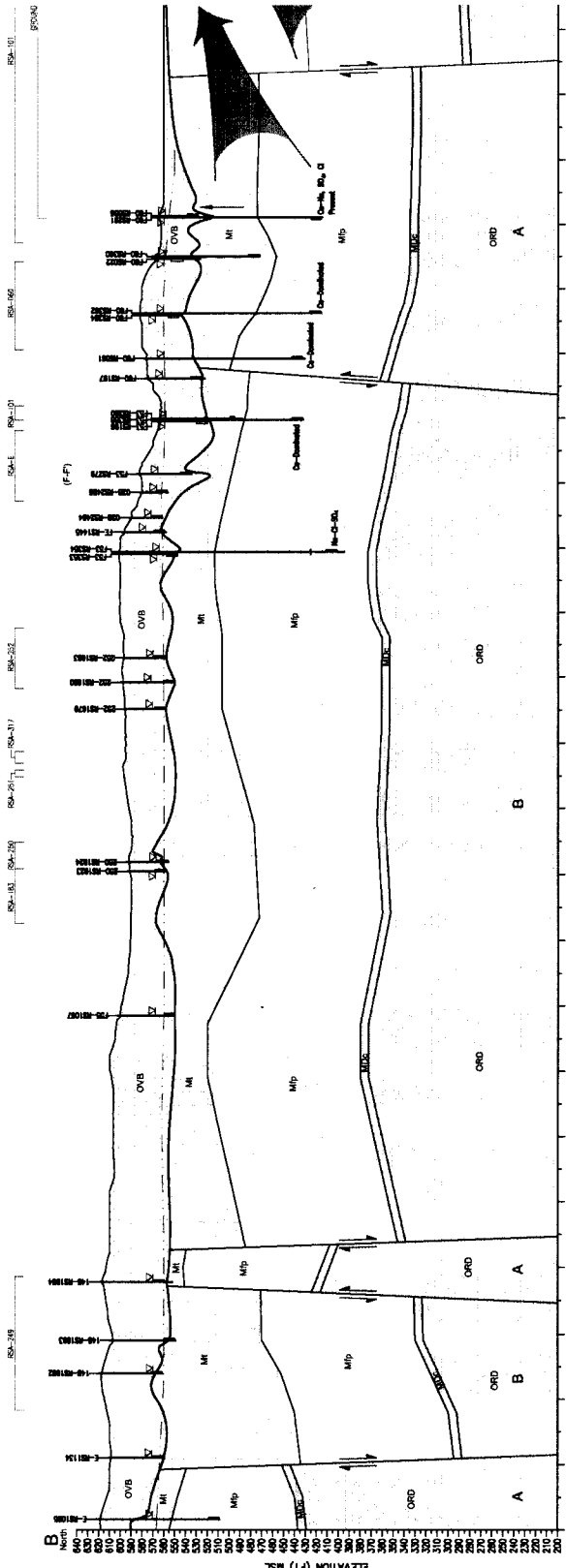
NSA-121

NSA-122

NSA-123

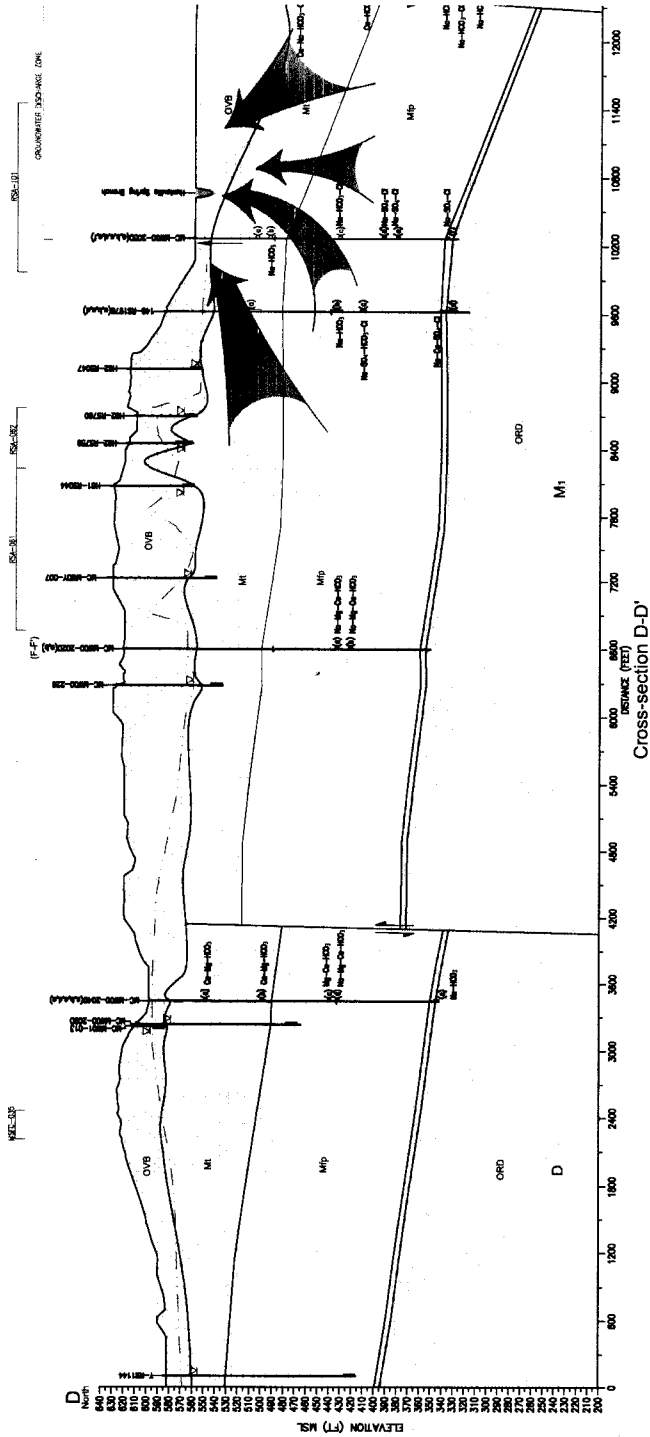
NSA-124

NSA-125

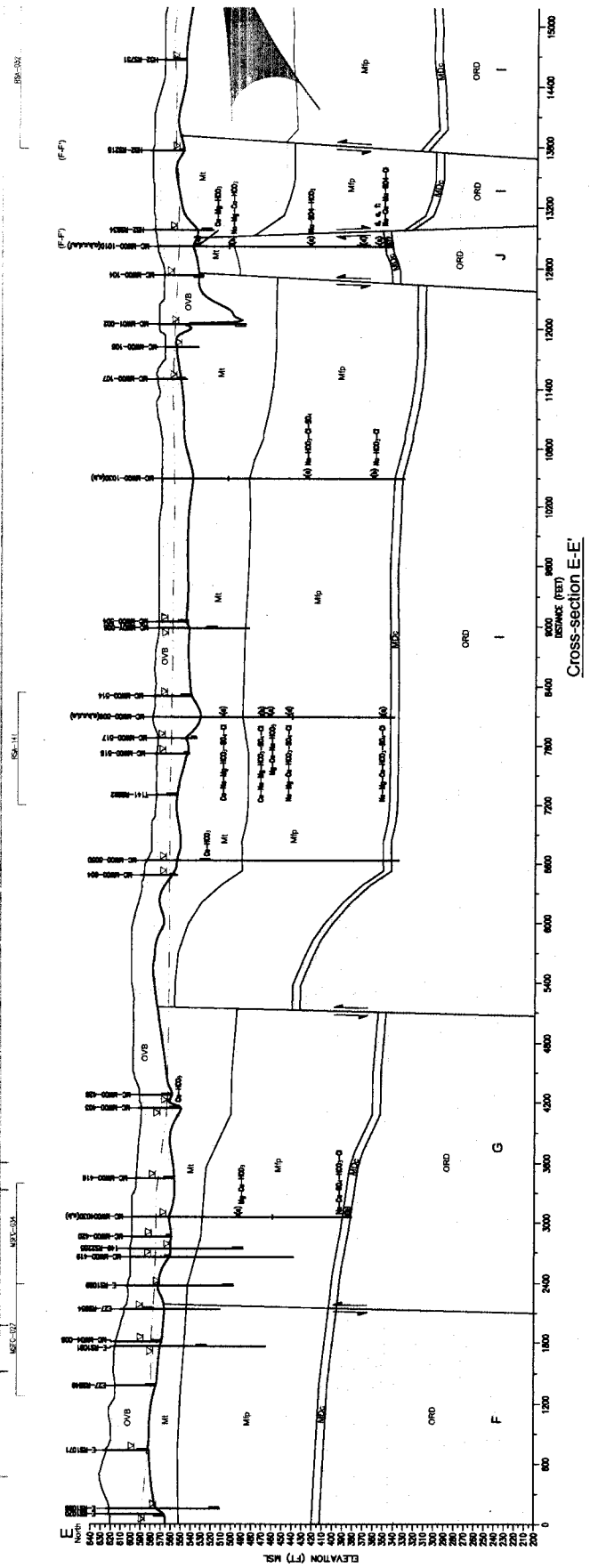


Cross-section B-B'

RSA-148



RSA-141 RSA-49 RSA-13 RSA-148 RSA-149





CR3-A, 1307.73

CR5-C, 420.7

- CR3-BC -

SP: 200.0 400.0 600.0 800.0 1000.0 1200.0 1400.0 1600.0 1800.0 2000.0

Offset: 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 9752

0.000

0.025

0.050

0.075

0.100

0.125

0.150

0.175

0.200

0.225

0.250

0.275

0.300

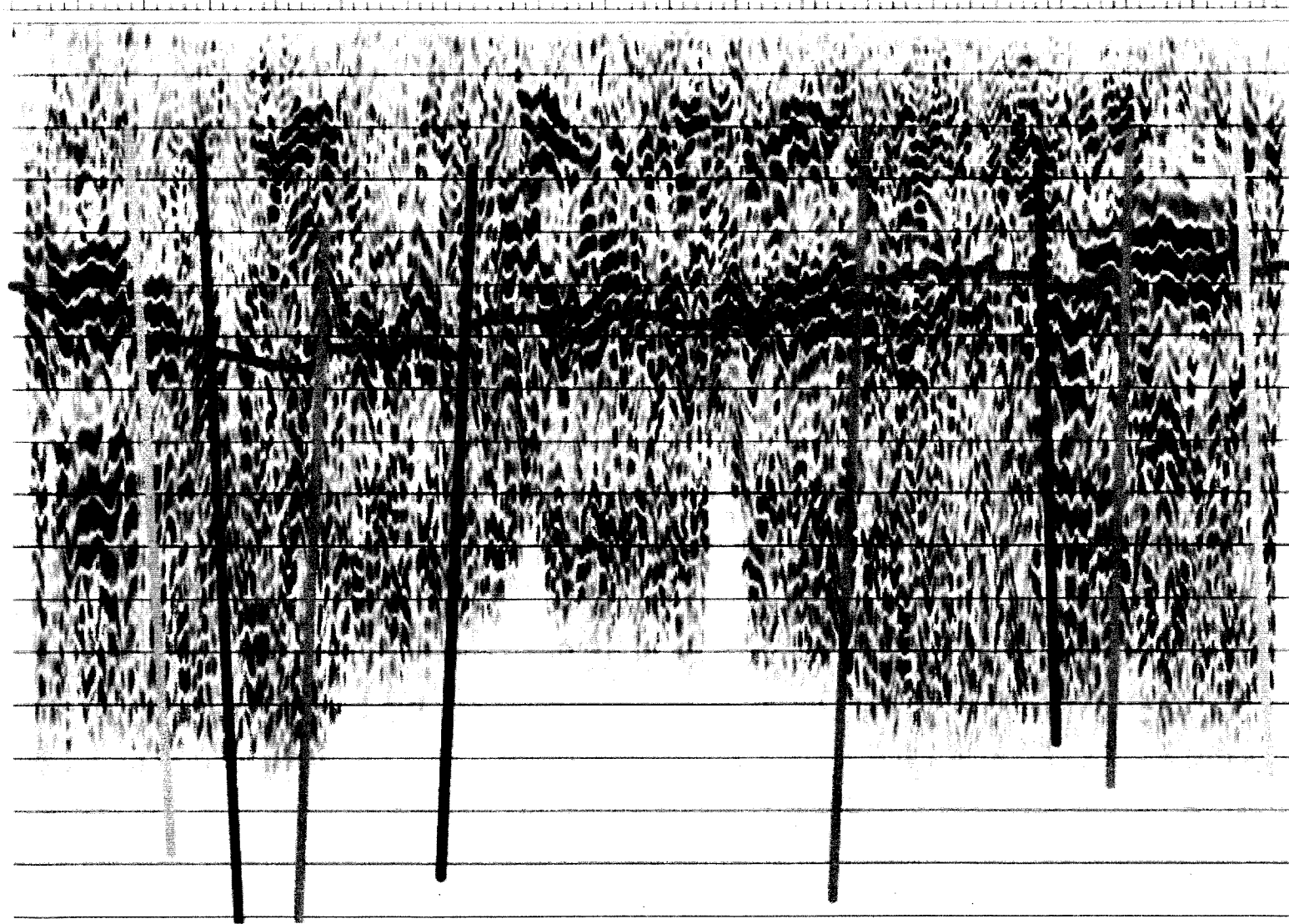
0.325

0.350

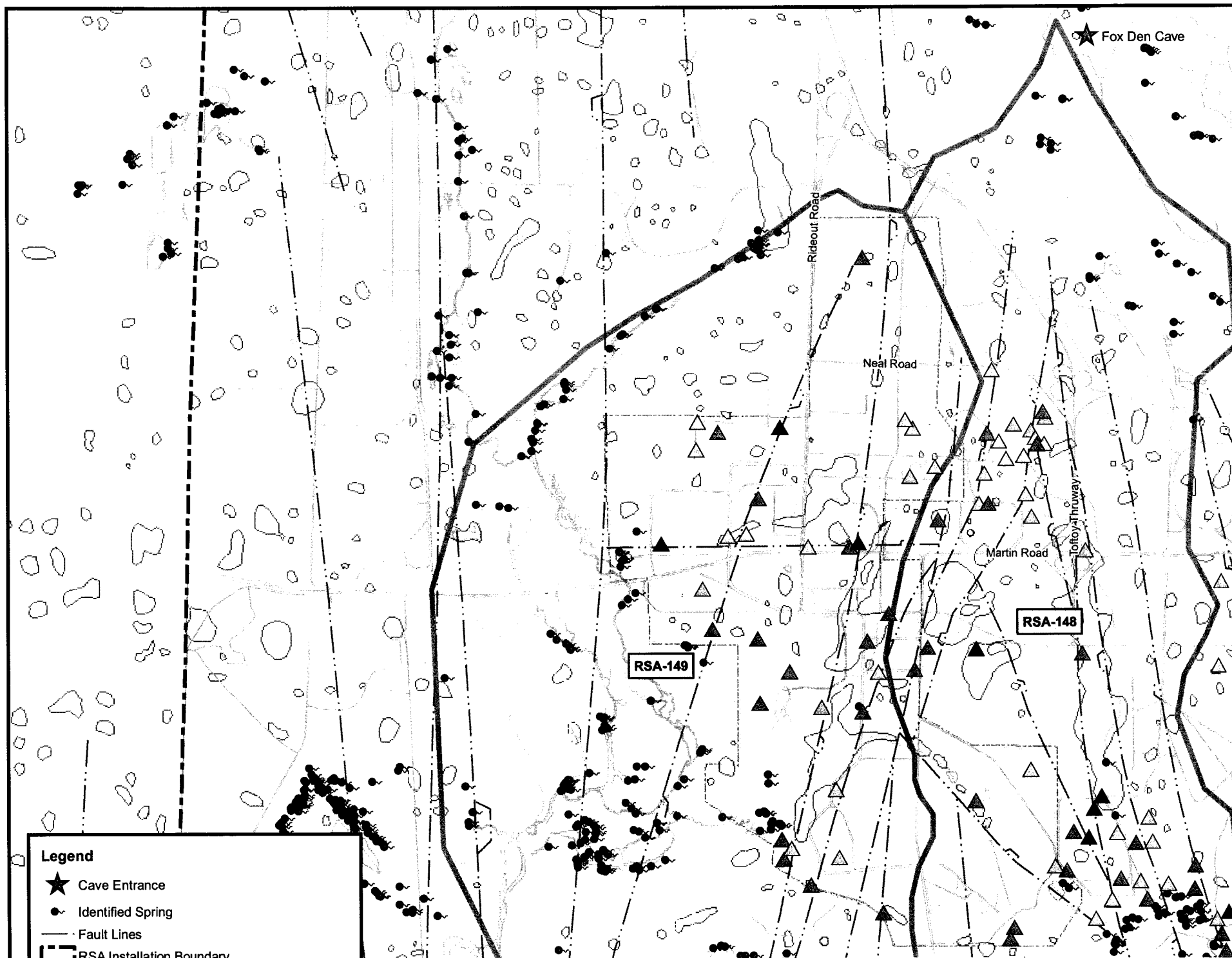
0.375

0.400

0.425

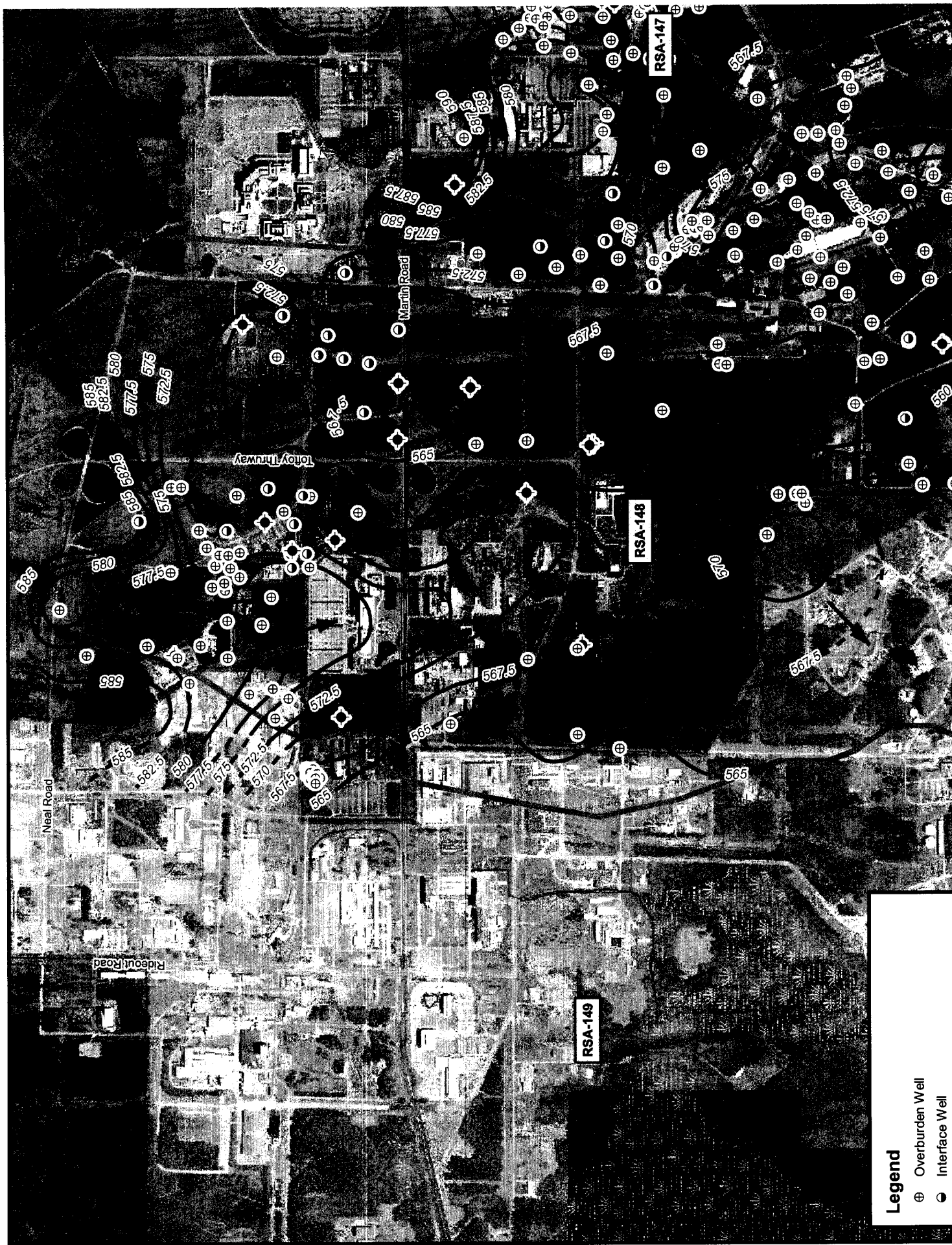


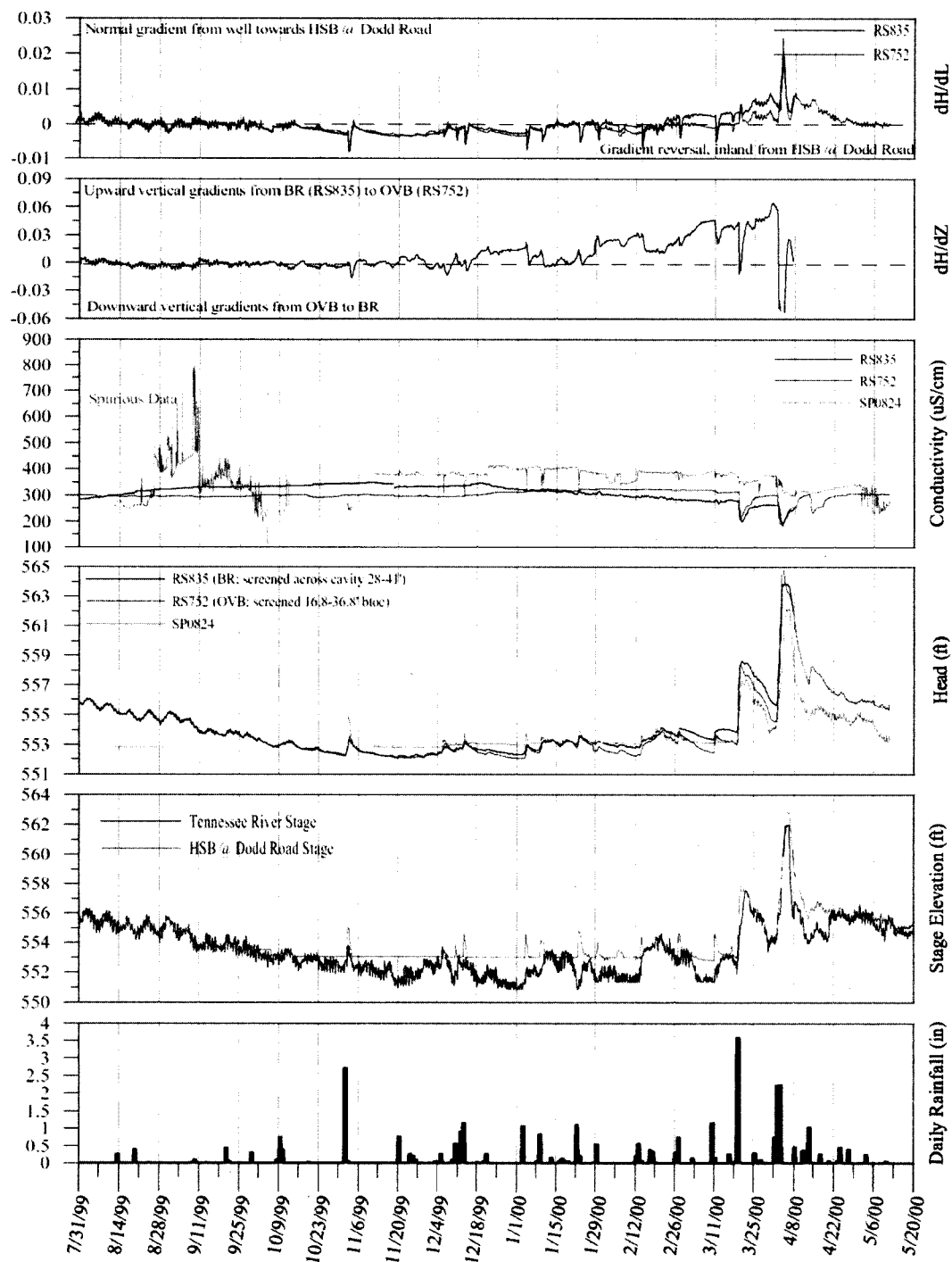










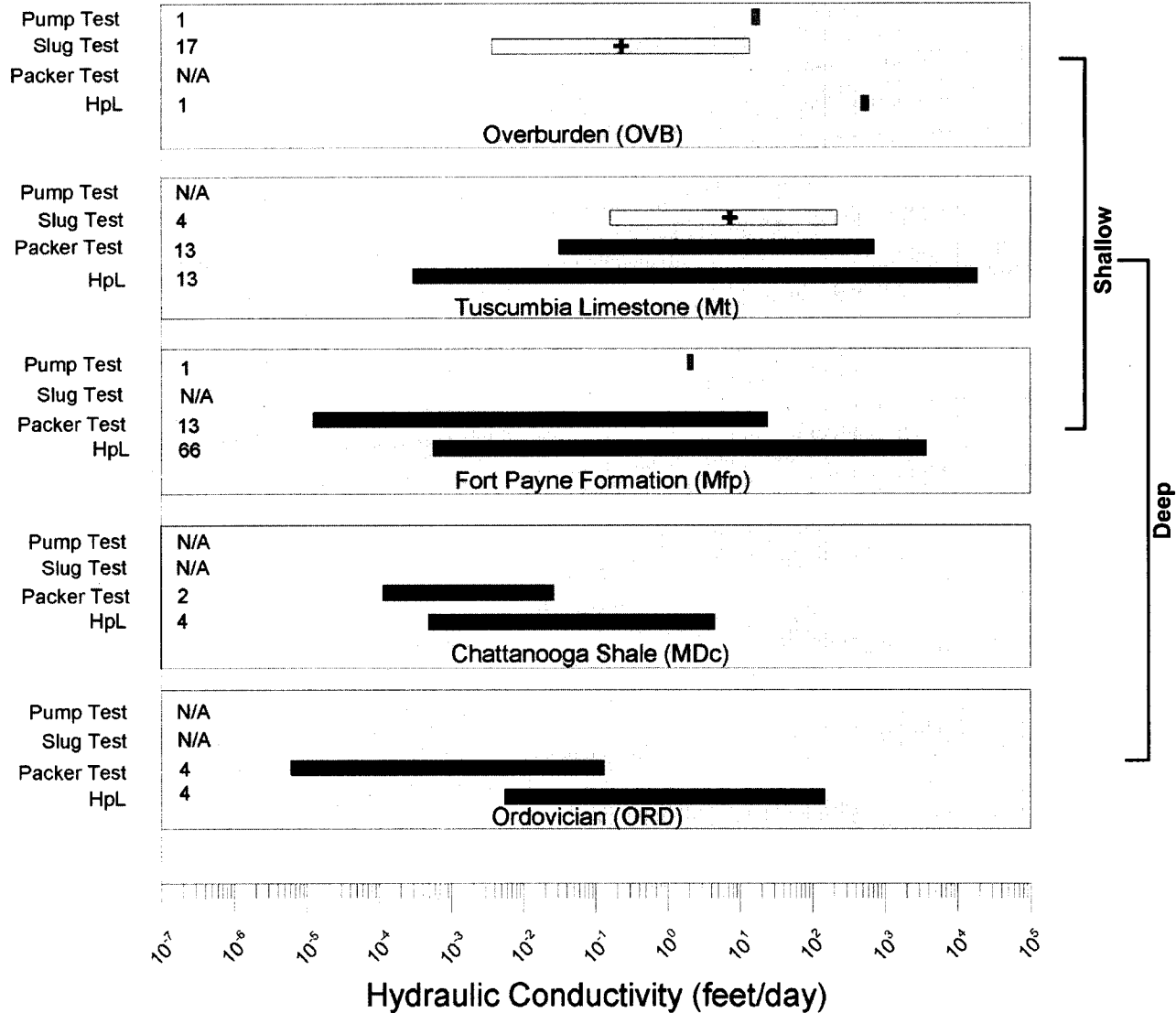


**Figure 3-10**

**Hydraulic Interactions from Continuous Monitoring**

Redstone Arsenal  
Madison County, Alabama  
Contract No. W91ZLK-09-D-0006





#### Notes:

HpL - Hydrophysical Logging

66 - Number of wells evaluated

"+" - Geometric mean value

N/A - No test completed

Specific measurement intervals within the Tuscumbia Limestone and Fort Payne Formation may be shallow (<120 feet bgs) or deep (>120 feet bgs) depending on the location.

#### Figure 3-11

**RSA-147, 148, and 149**  
**Hydraulic Conductivity by Geologic Formation**

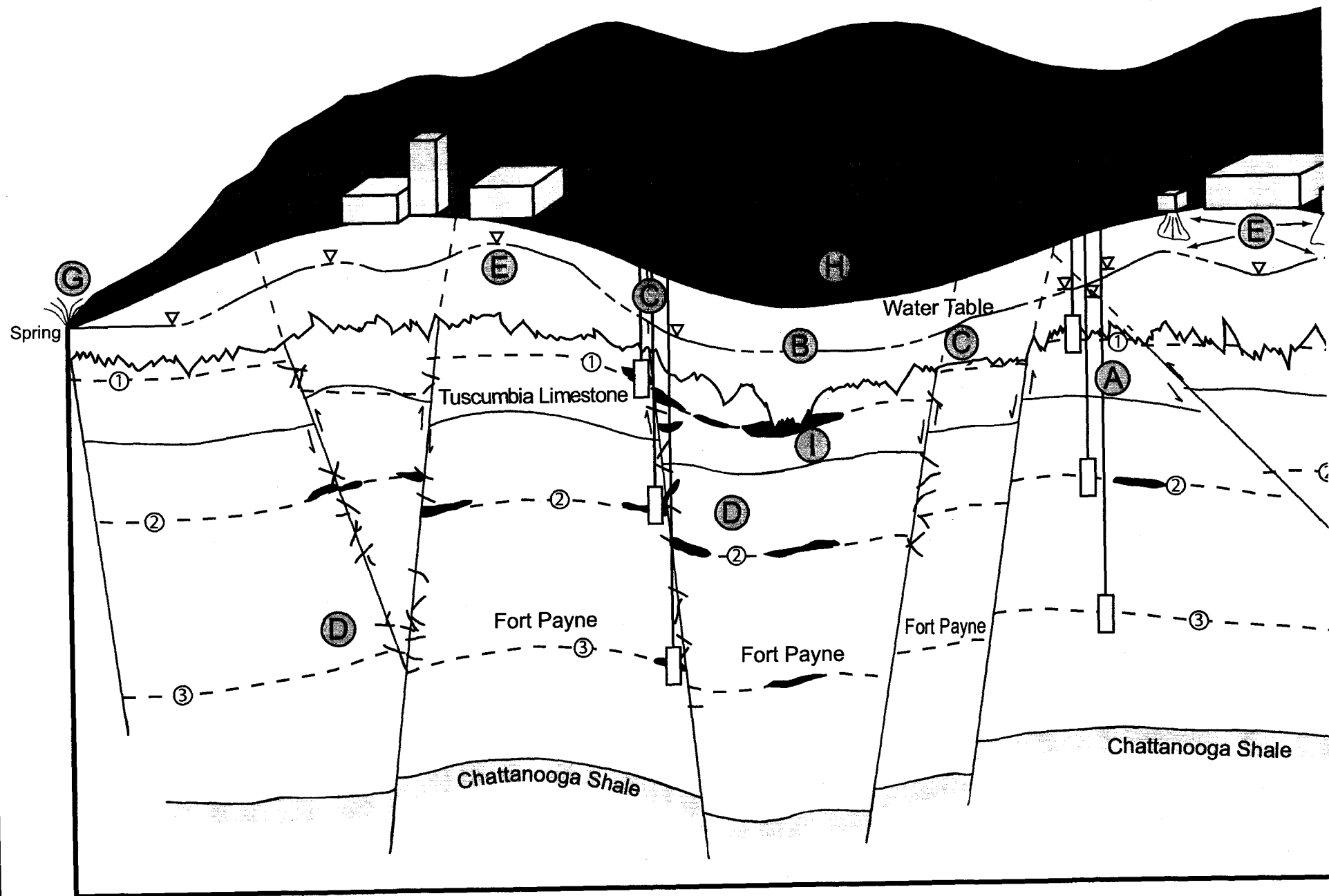
*Redstone Arsenal*

*Madison County, Alabama*

*Contract No. W91ZLK-09-D-0006*



West





MC-MW-024R  
MC-MW-033D  
MC-MW-030  
MC-MW-048D

MC-MW-026  
MC-MW-034D

RSA-149

● MC-MW00-503Dc-d

MC-MWDY-008

MC-MW00-102

H52-RS752

H52-RS835

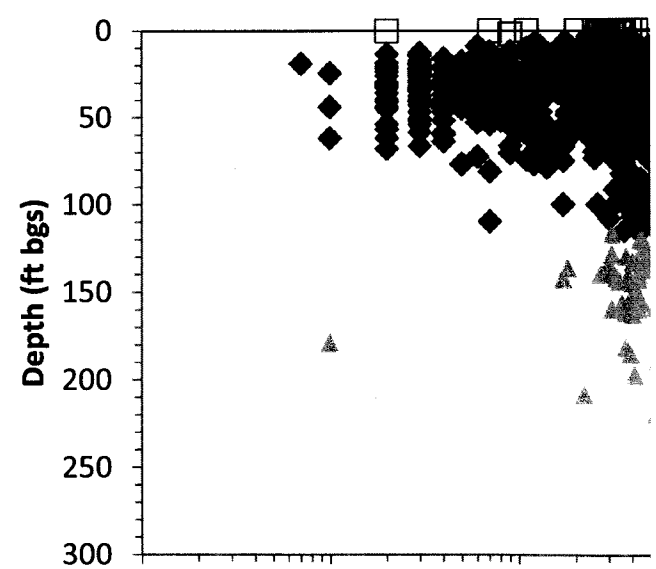
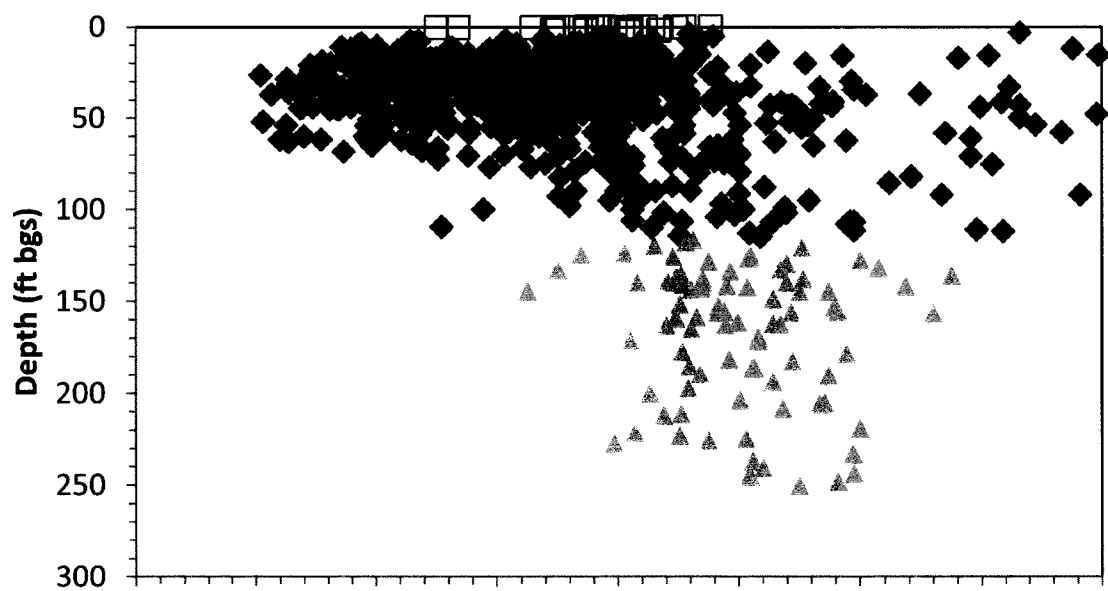
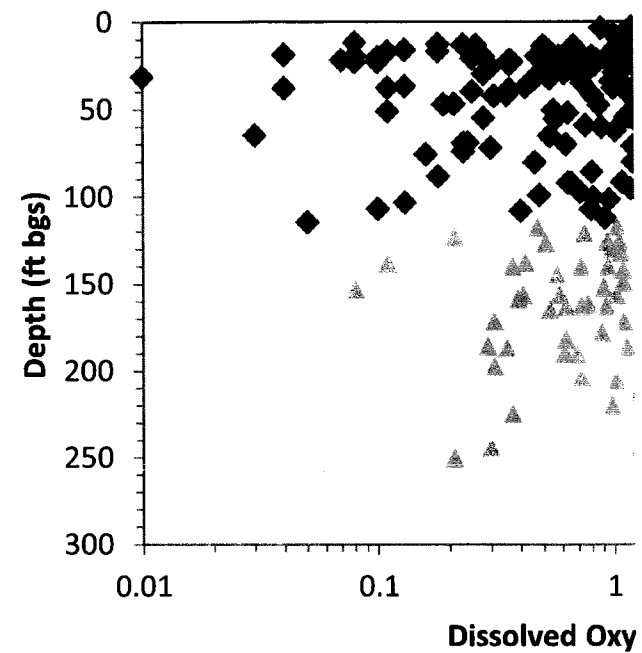
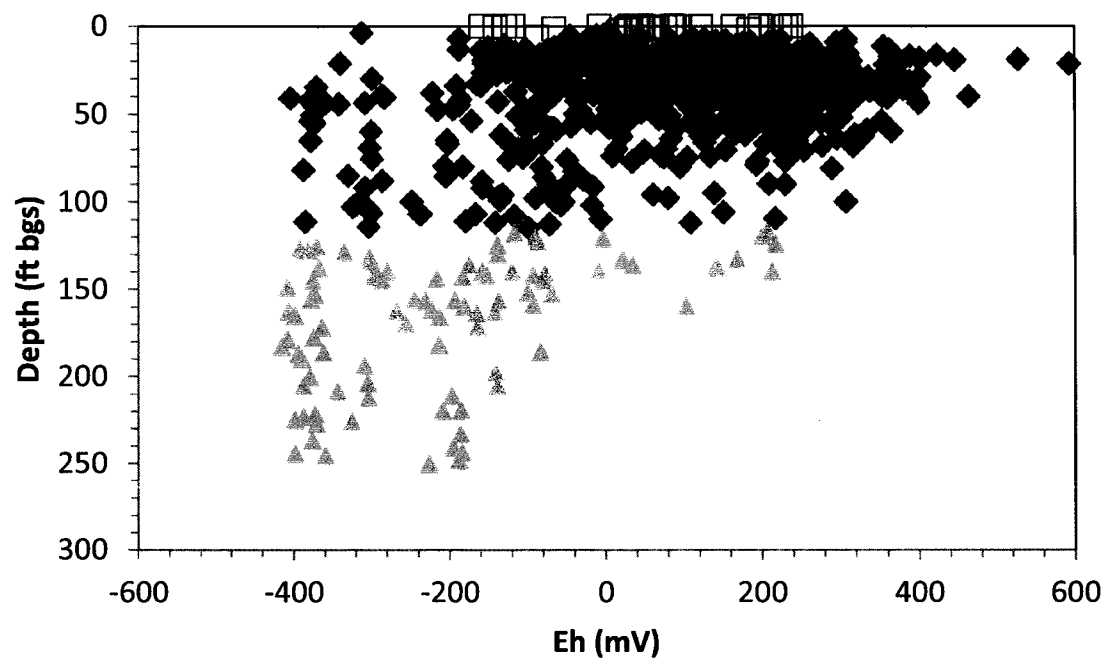
RSA-148

F10-RS396  
F10-RS236  
F10-RS094

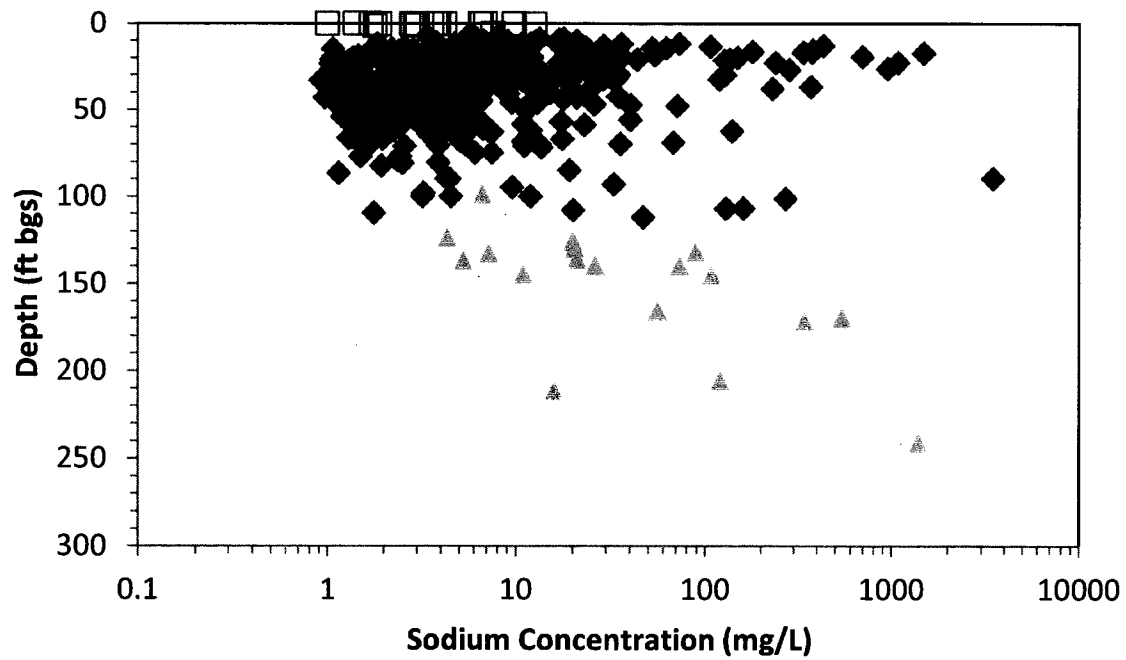
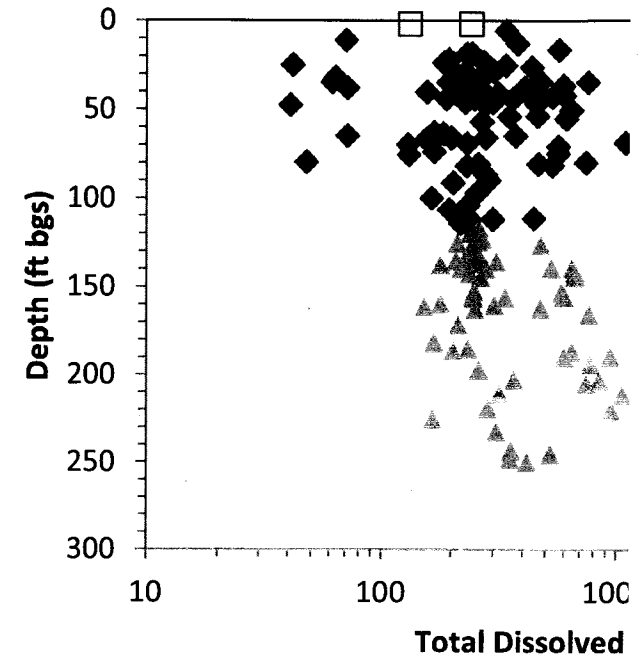
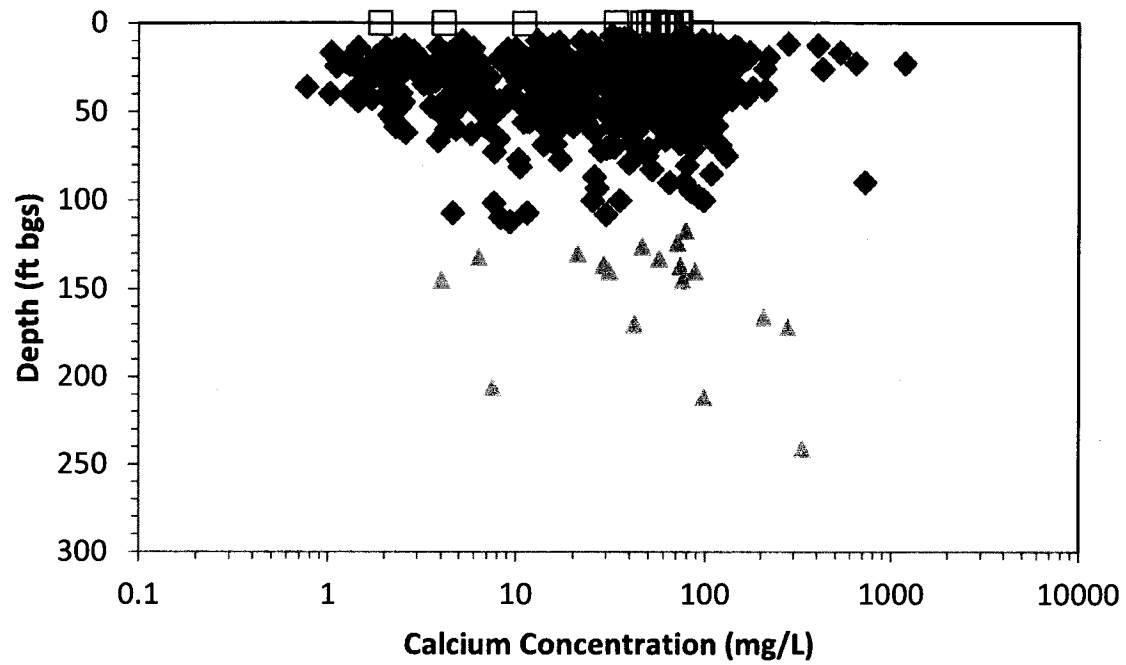
F60-RS022  
F60-RS198  
F60-RS291  
F60-RS023  
F60-RS556

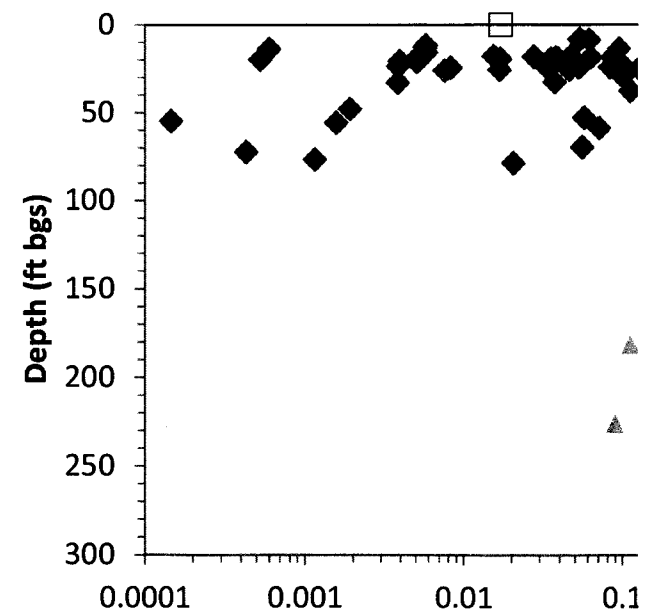
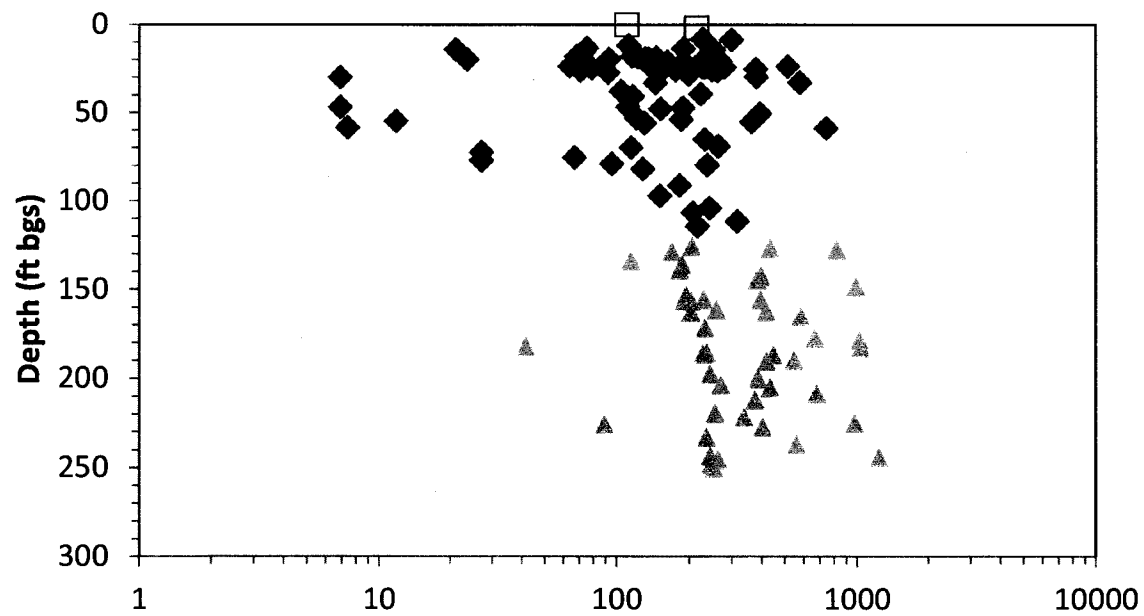
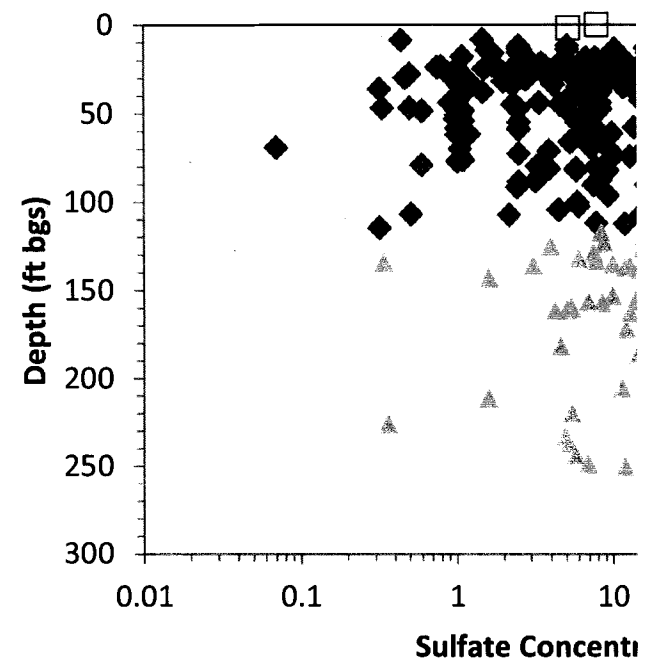
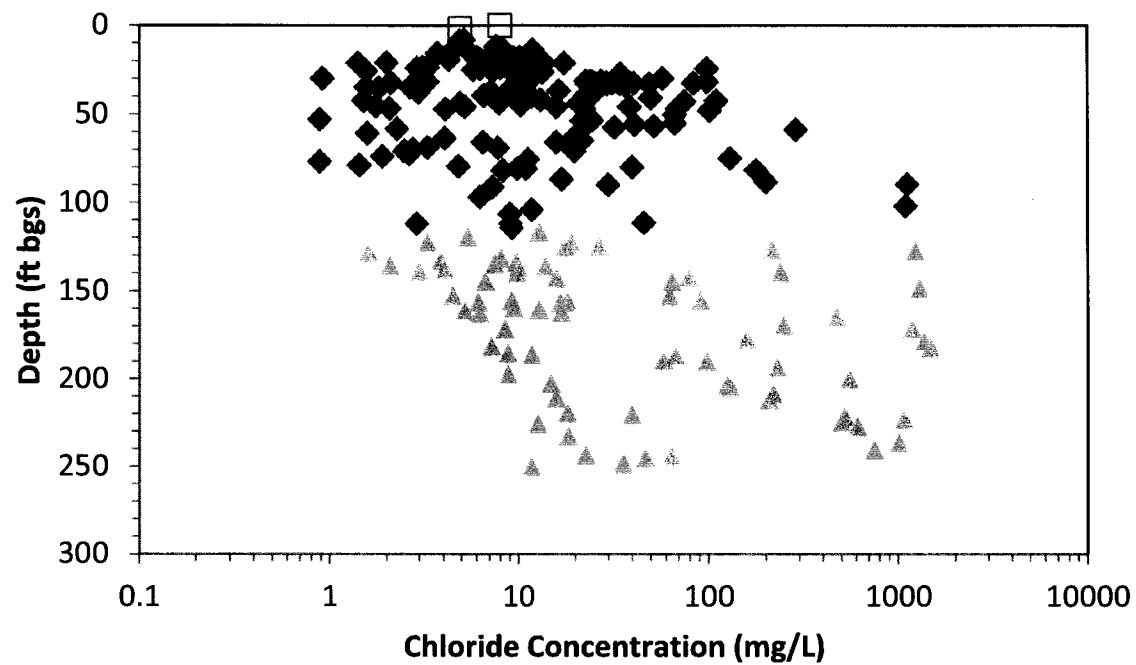
F53-RS1  
F53-RS  
F53-RS

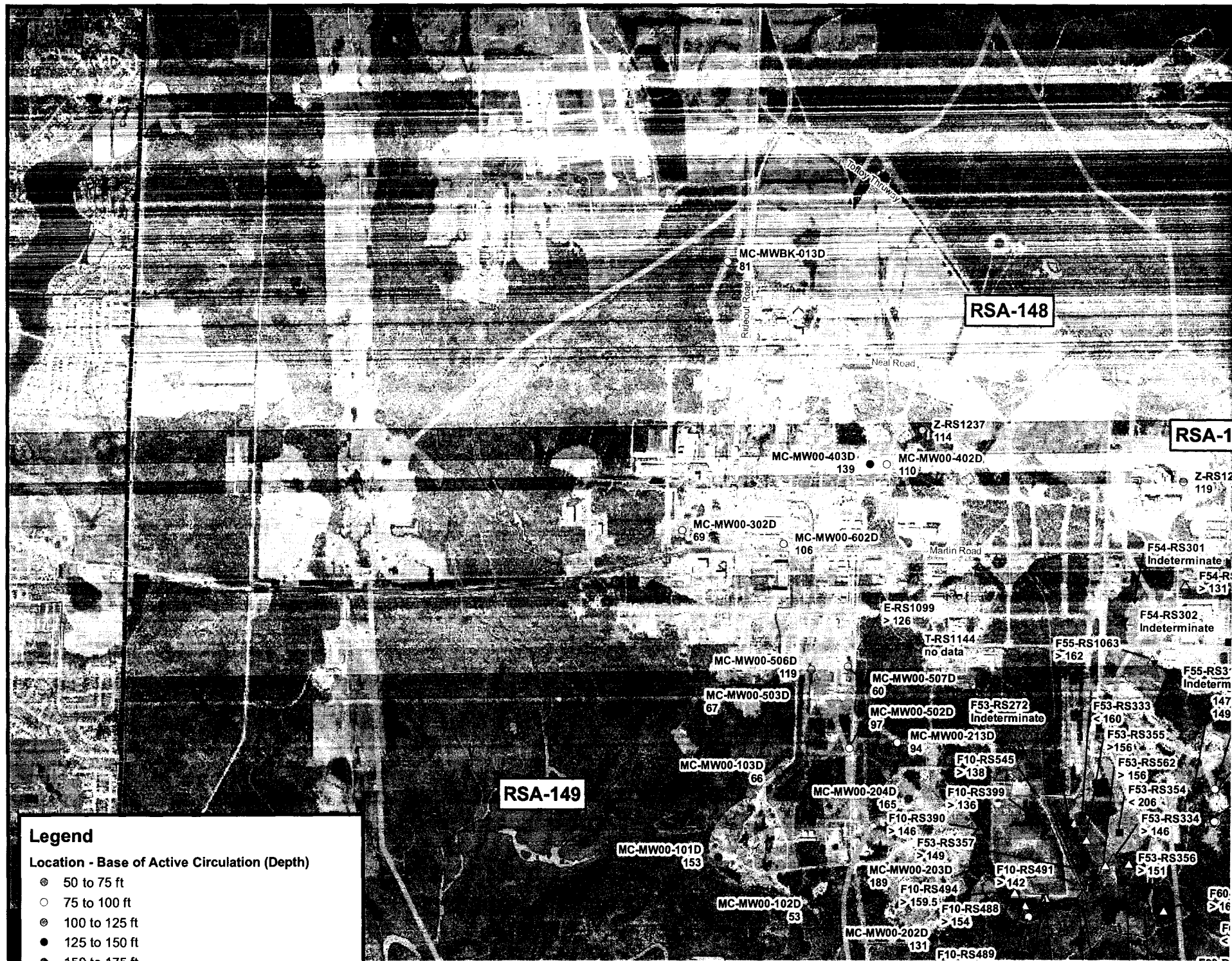
F6  
F6  
F

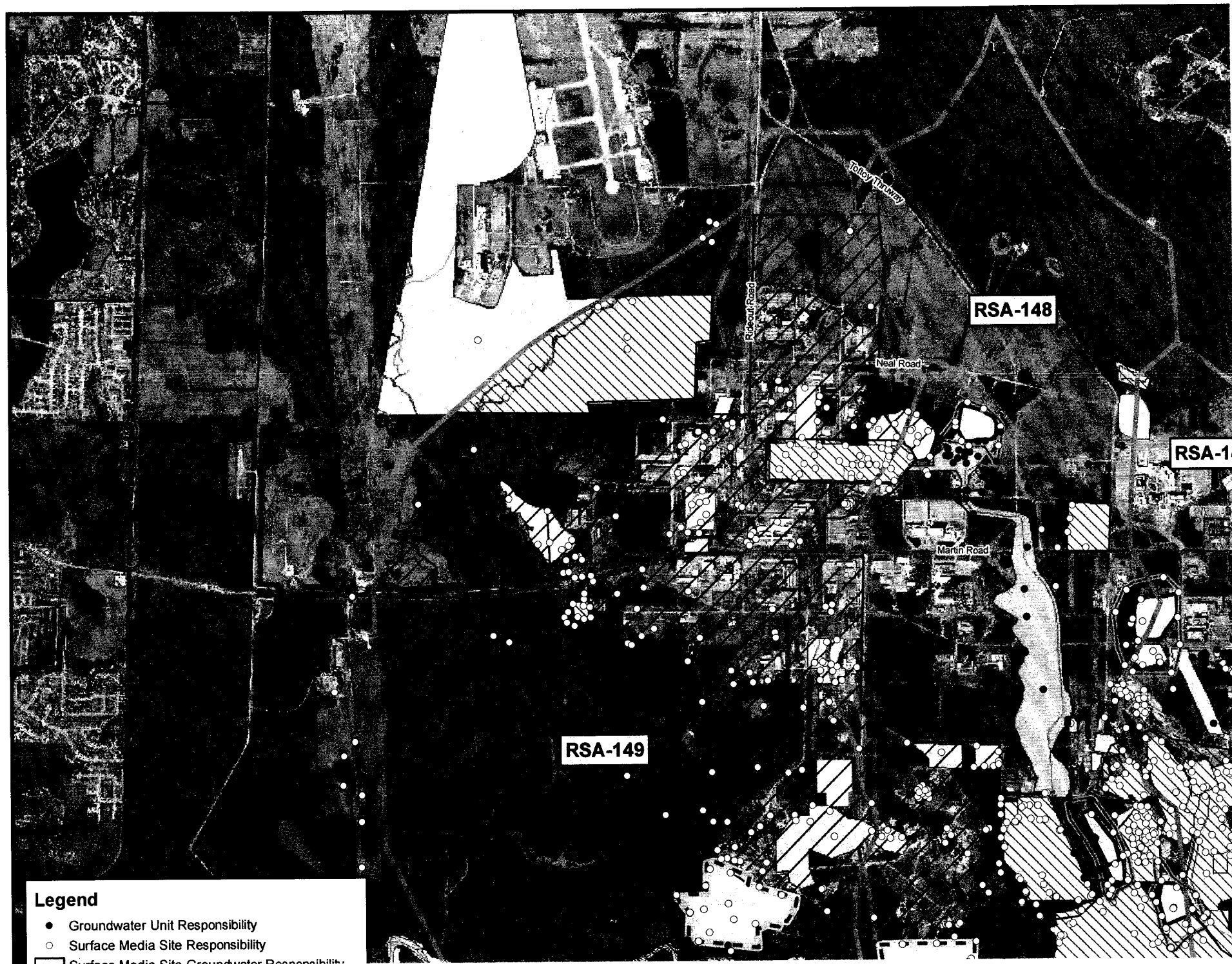


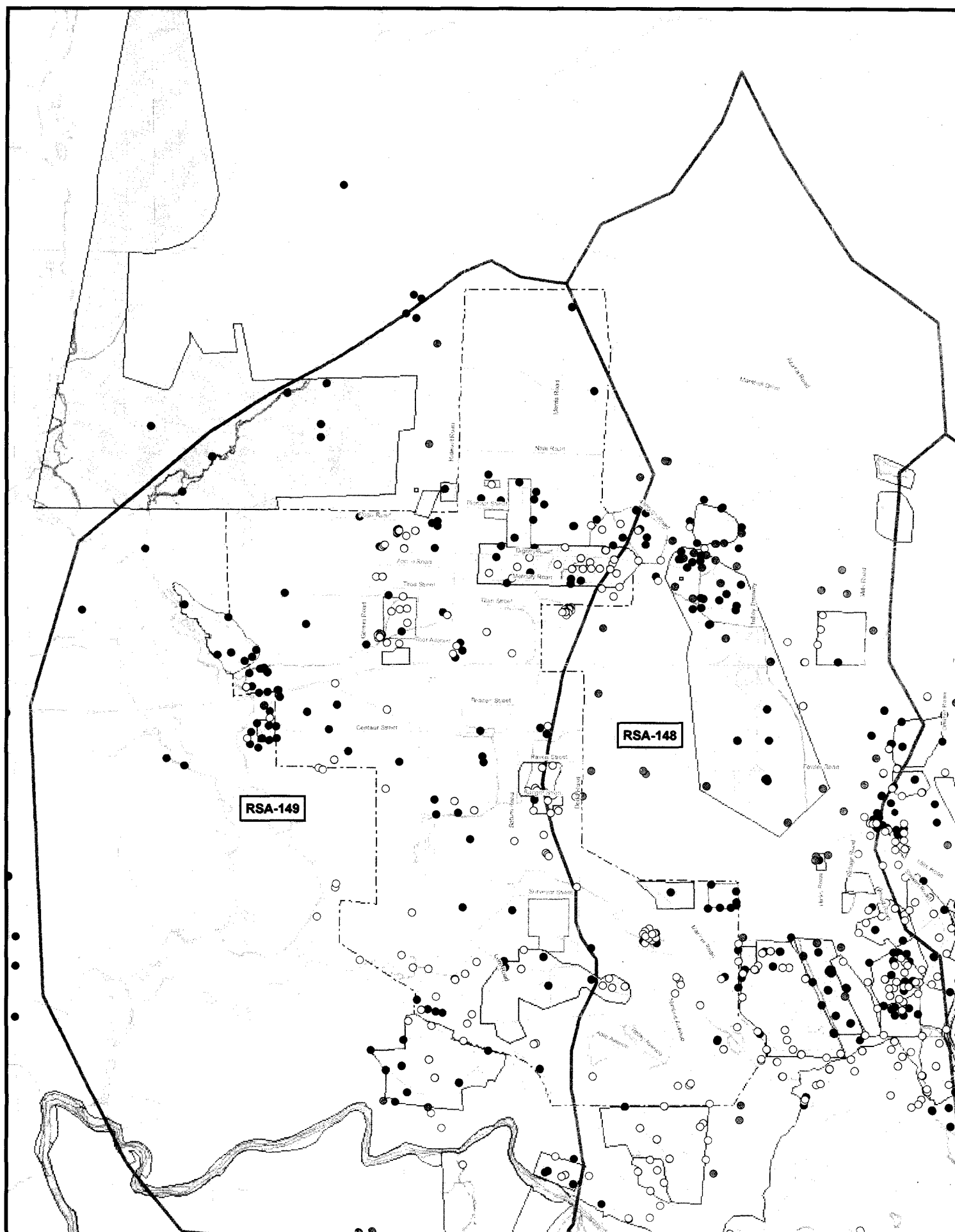


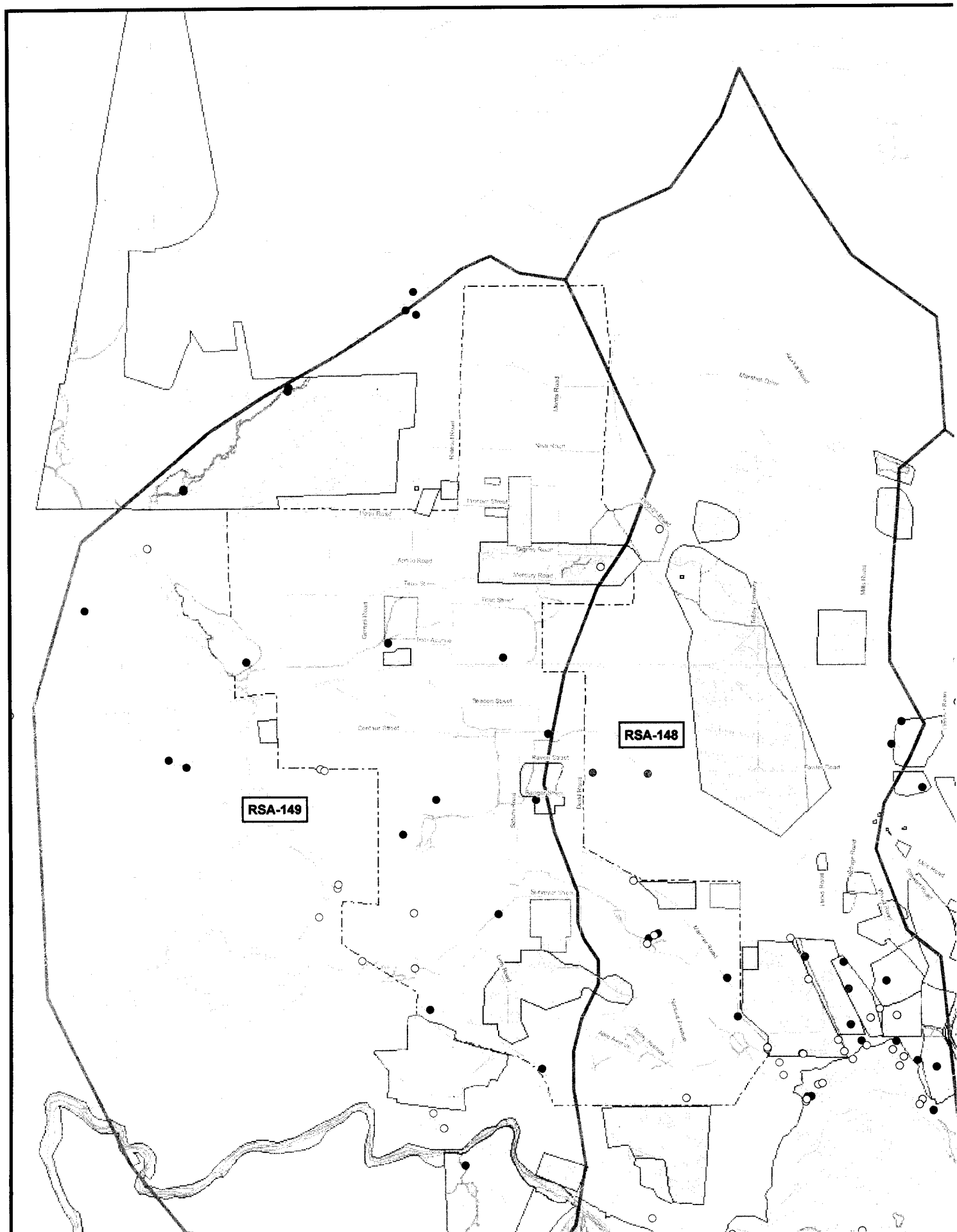




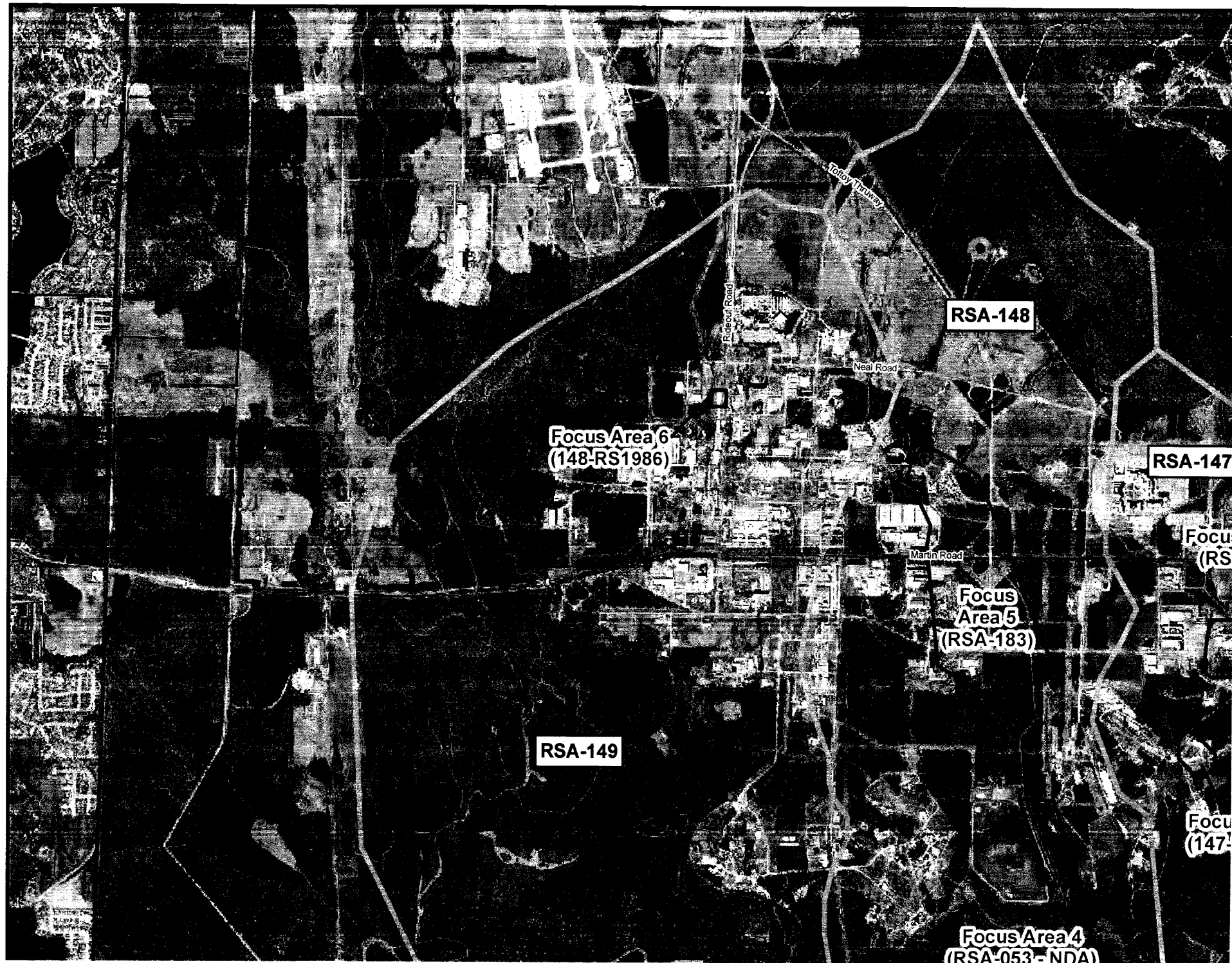


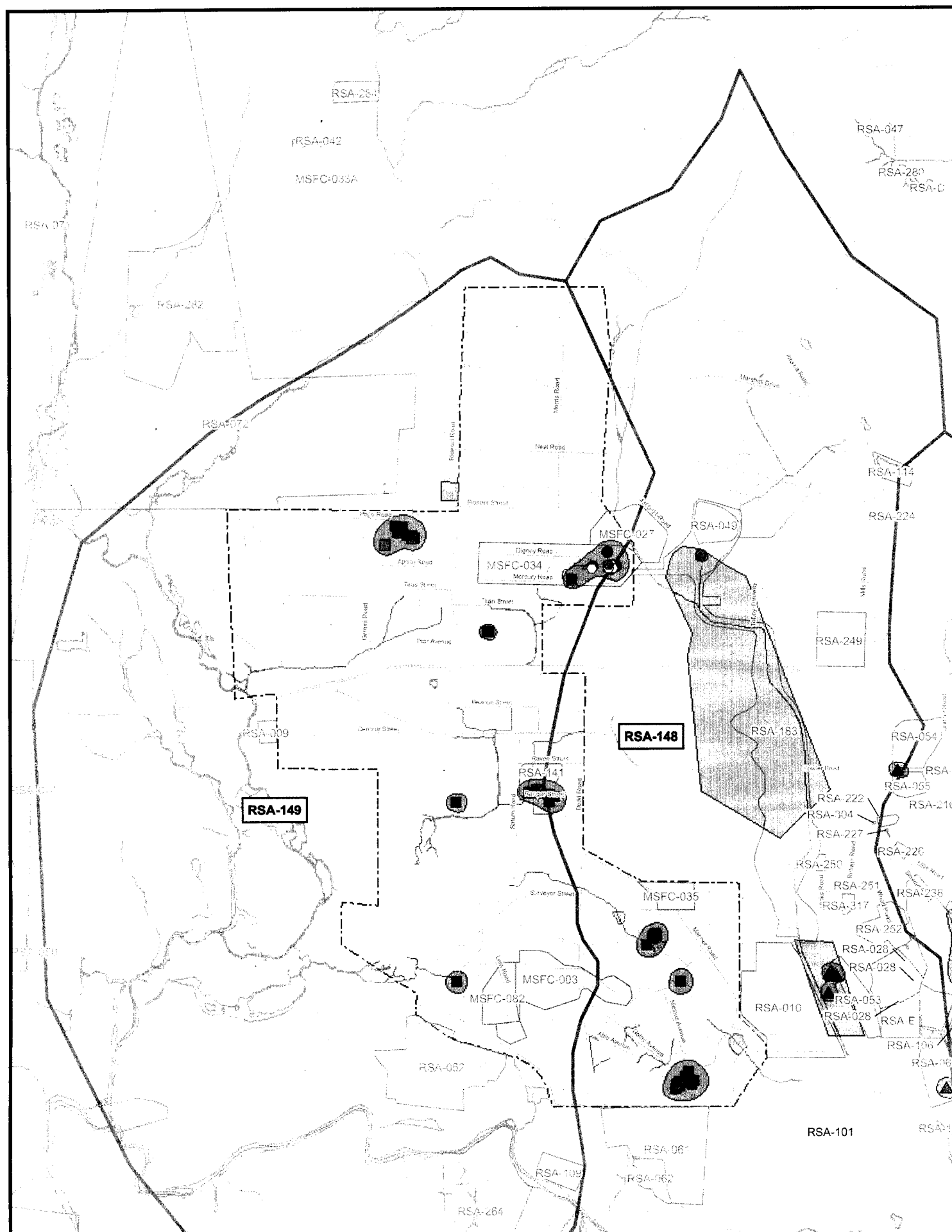




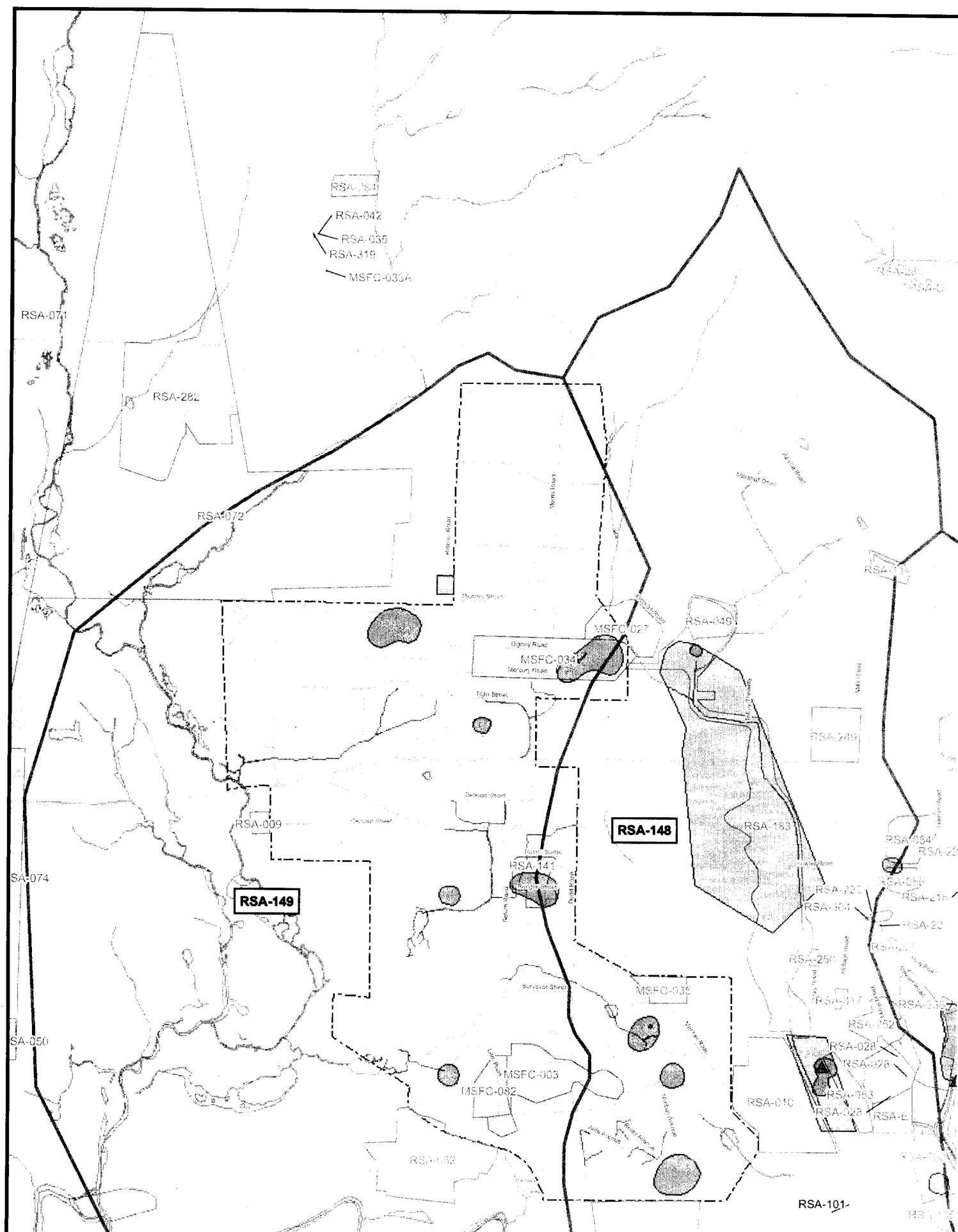


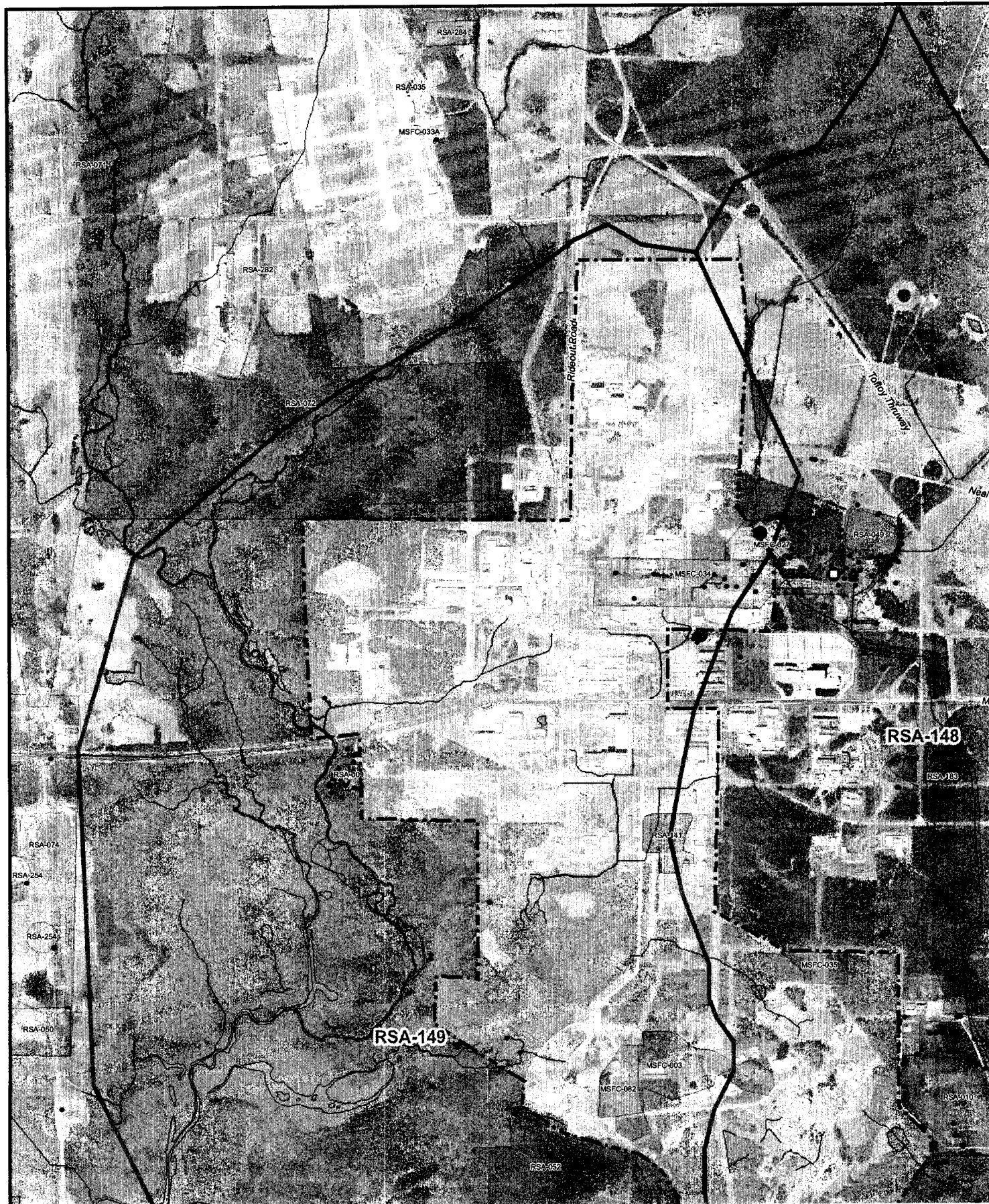




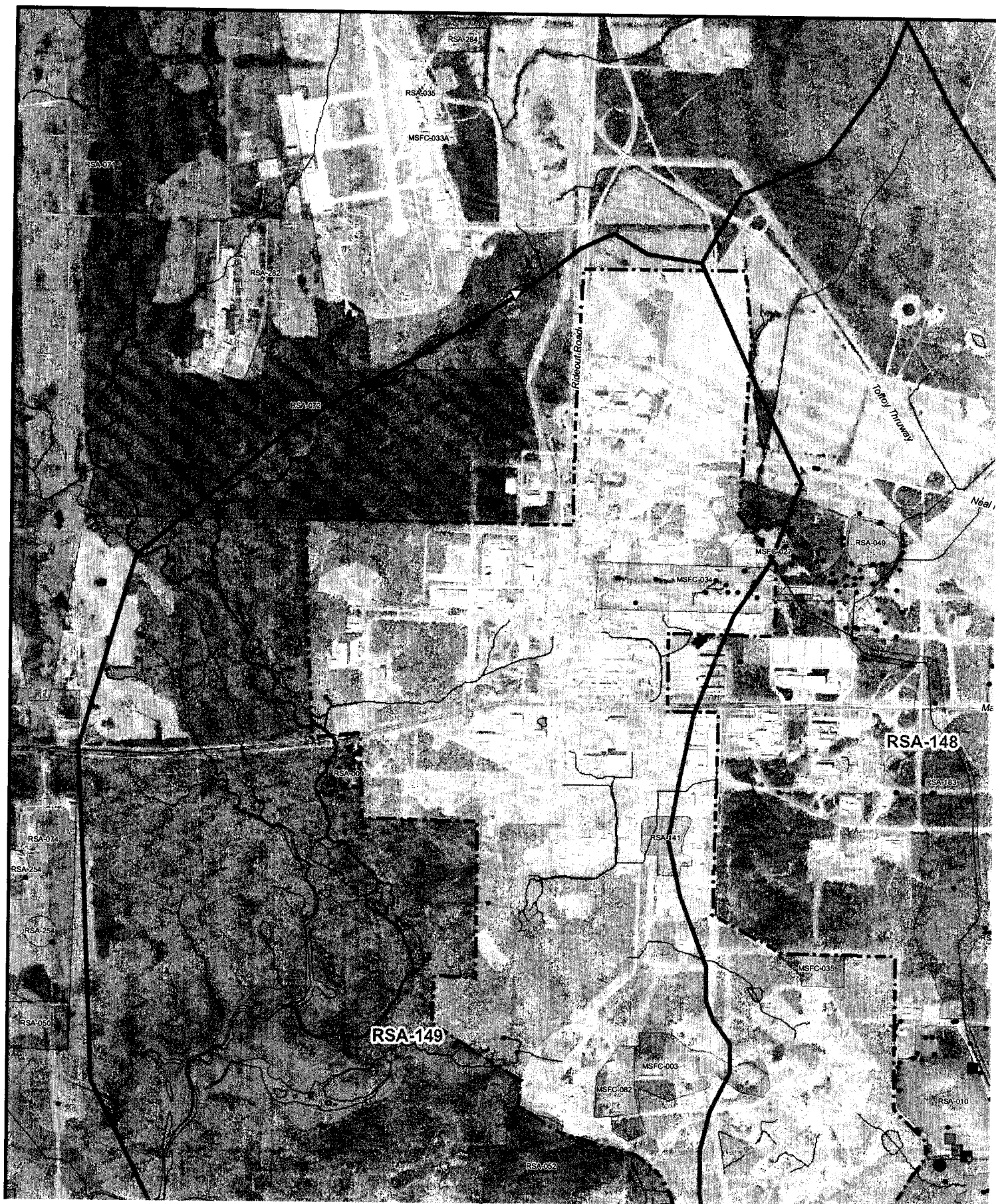


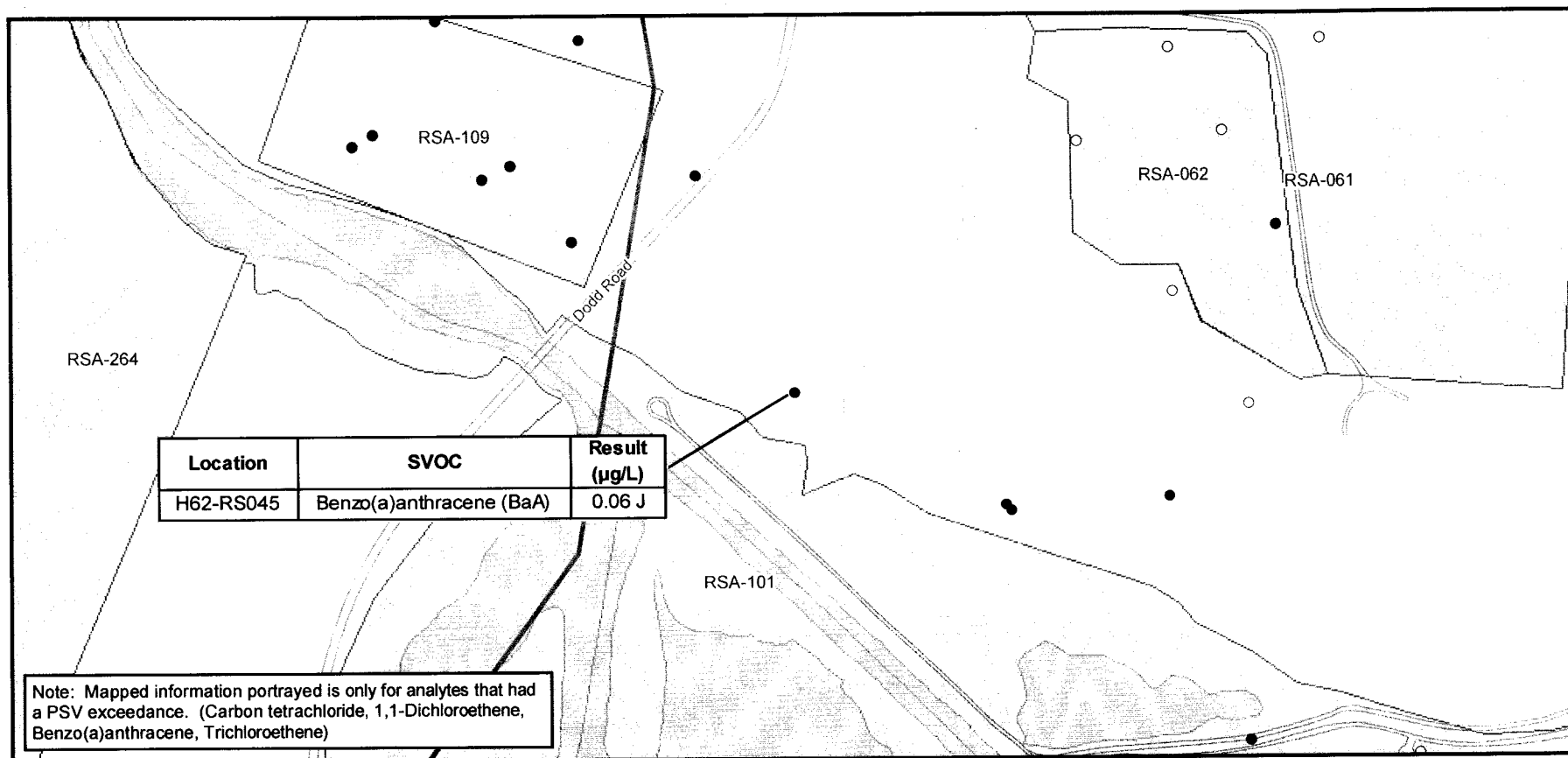












## Legend

### Groundwater Unit Responsibility

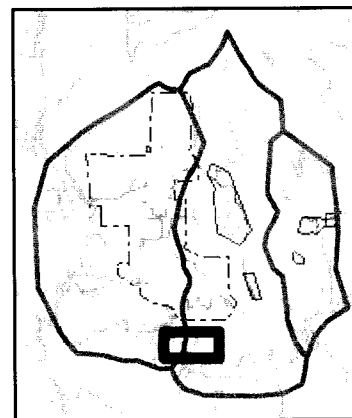
- > Preliminary Screening Value
- < Preliminary Screening Value or Non-Detect

### Surface Media Site Responsibility

- > Preliminary Screening Value
- < Preliminary Screening Value or Non-Detect

- Groundwater Focus Areas
- RSA-147, RSA-148, and RSA-149 Unit Boundary
- NASA-MSFC Boundary Exclusion Area
- Surface Media Site Delineation Responsibility

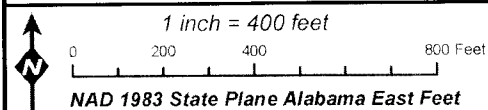
- Surface Drainage Features (some ephemeral)
- Water Bodies
- NWI Classified Wetland

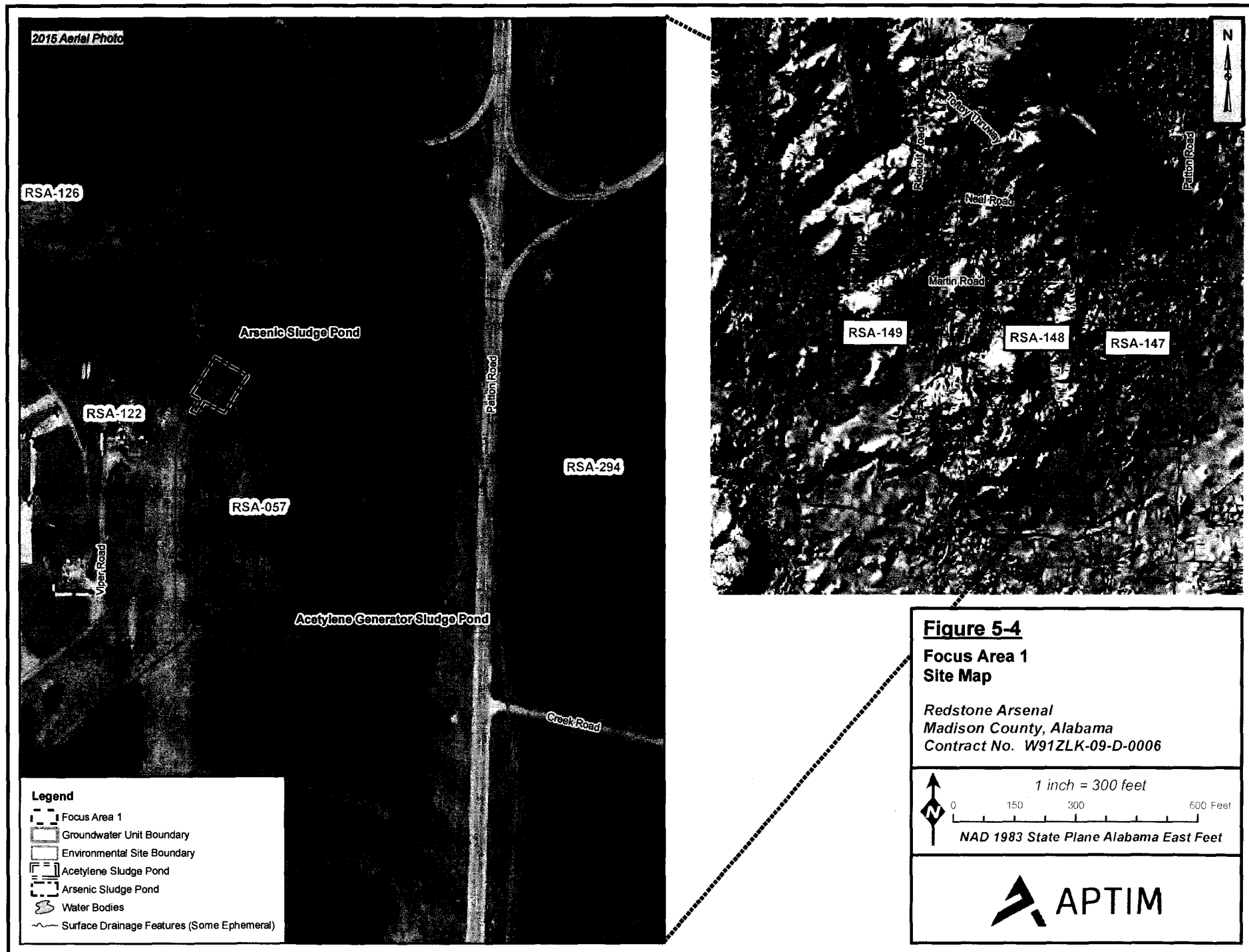


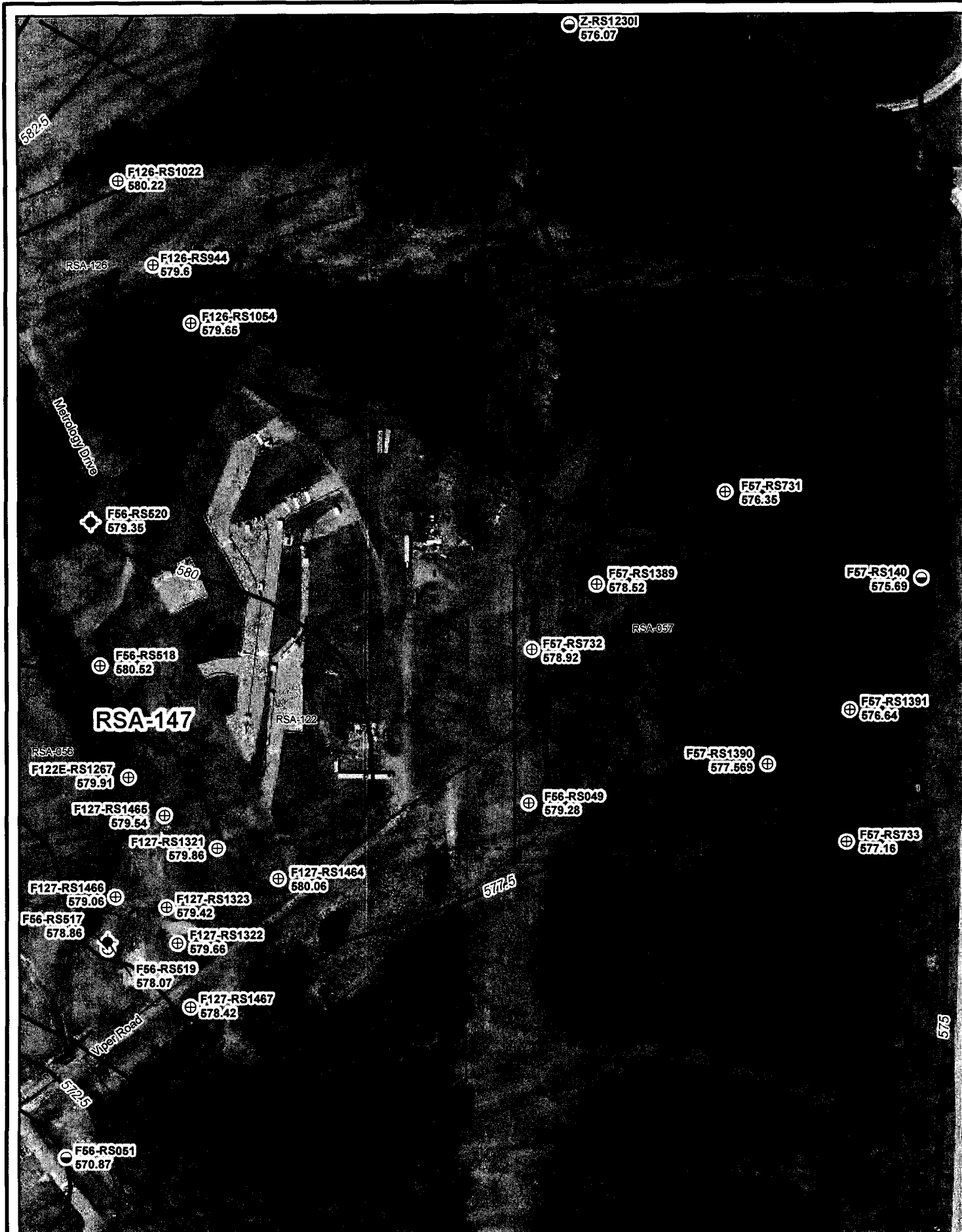
## Figure 5-3

### RSA-147, RSA-148, and RSA-149 PSV Exceedances in Groundwater Unit-Responsible Samples Outside Focus Areas

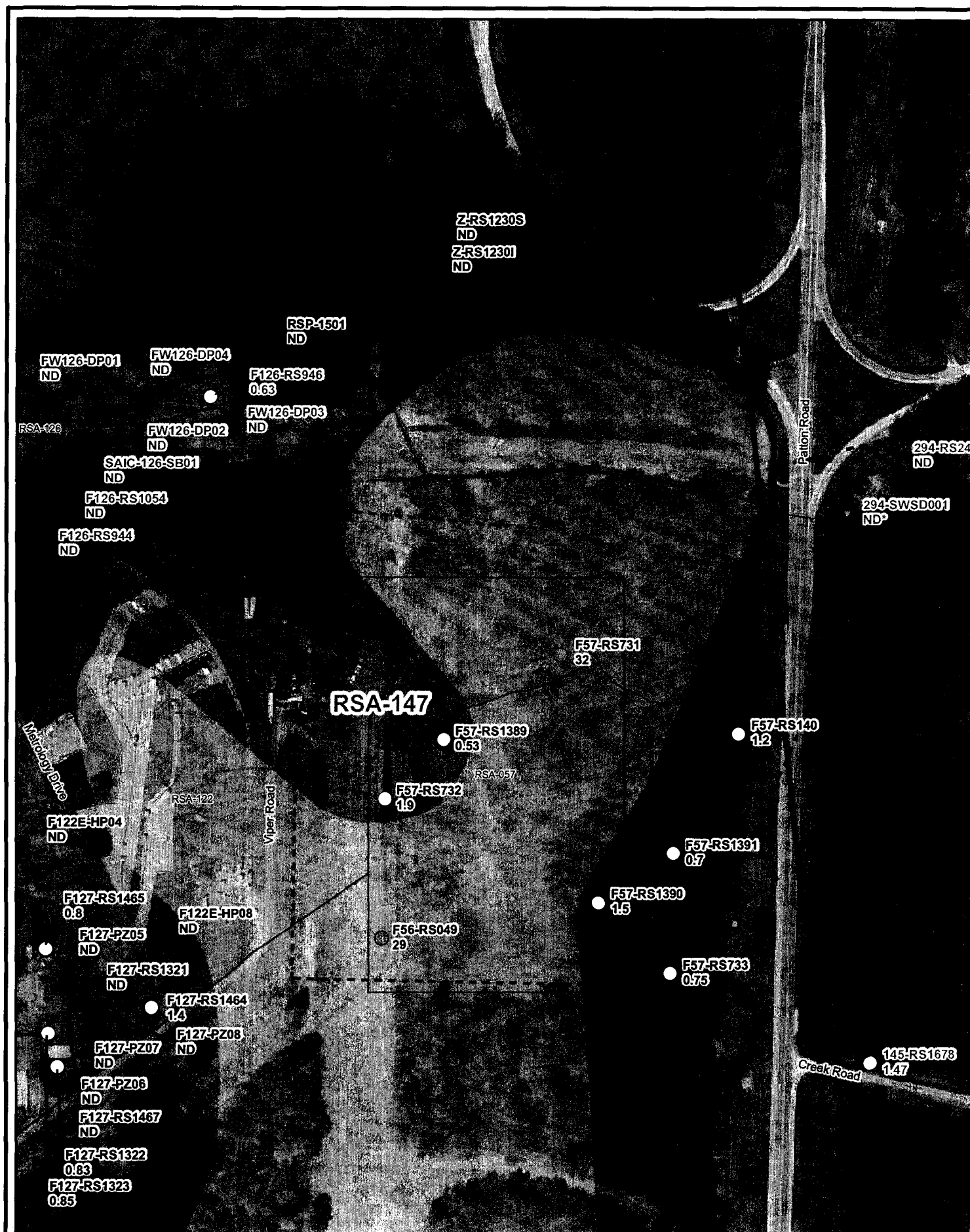
Redstone Arsenal  
Madison County, Alabama  
Contract No. W91ZLK-09-D-0006







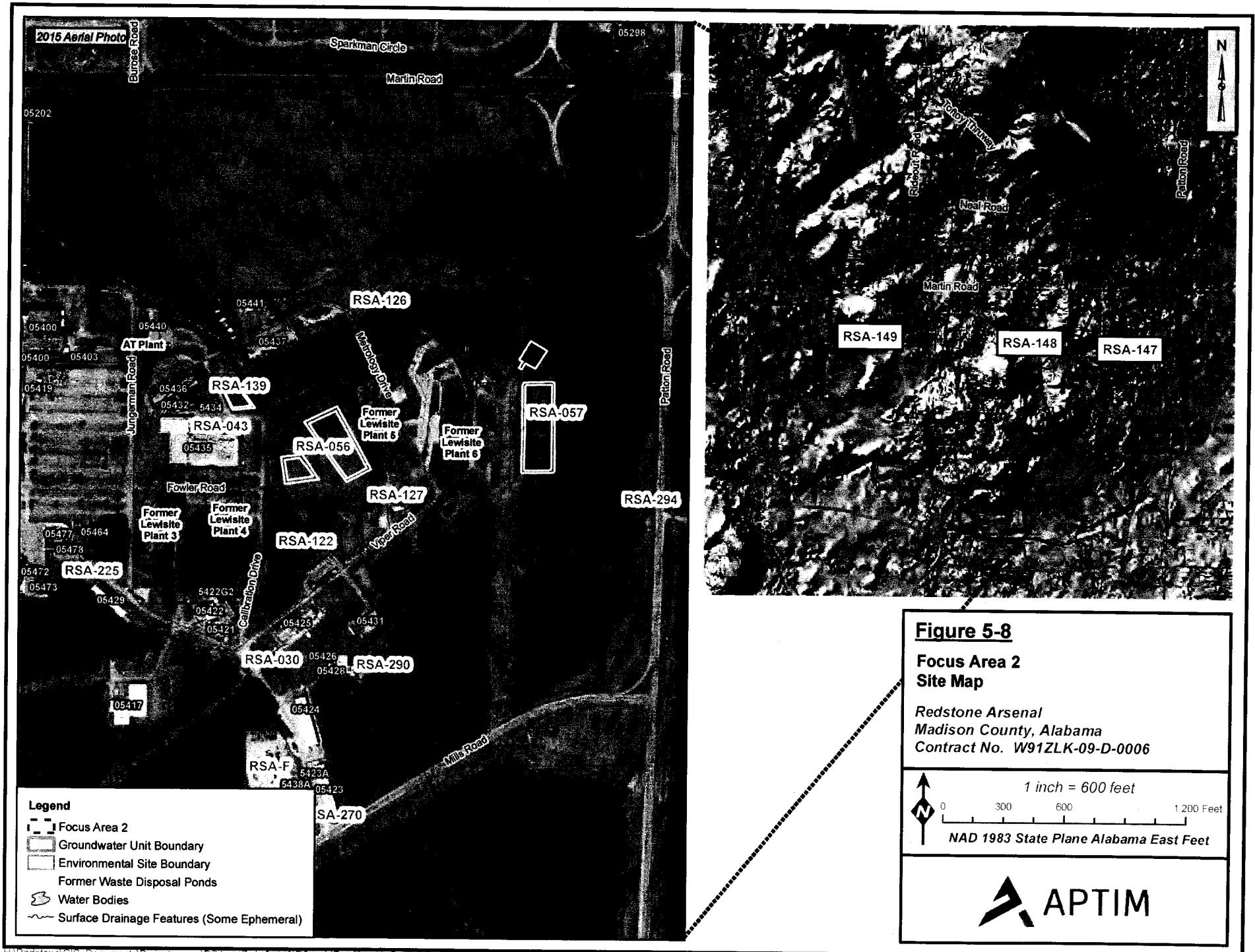


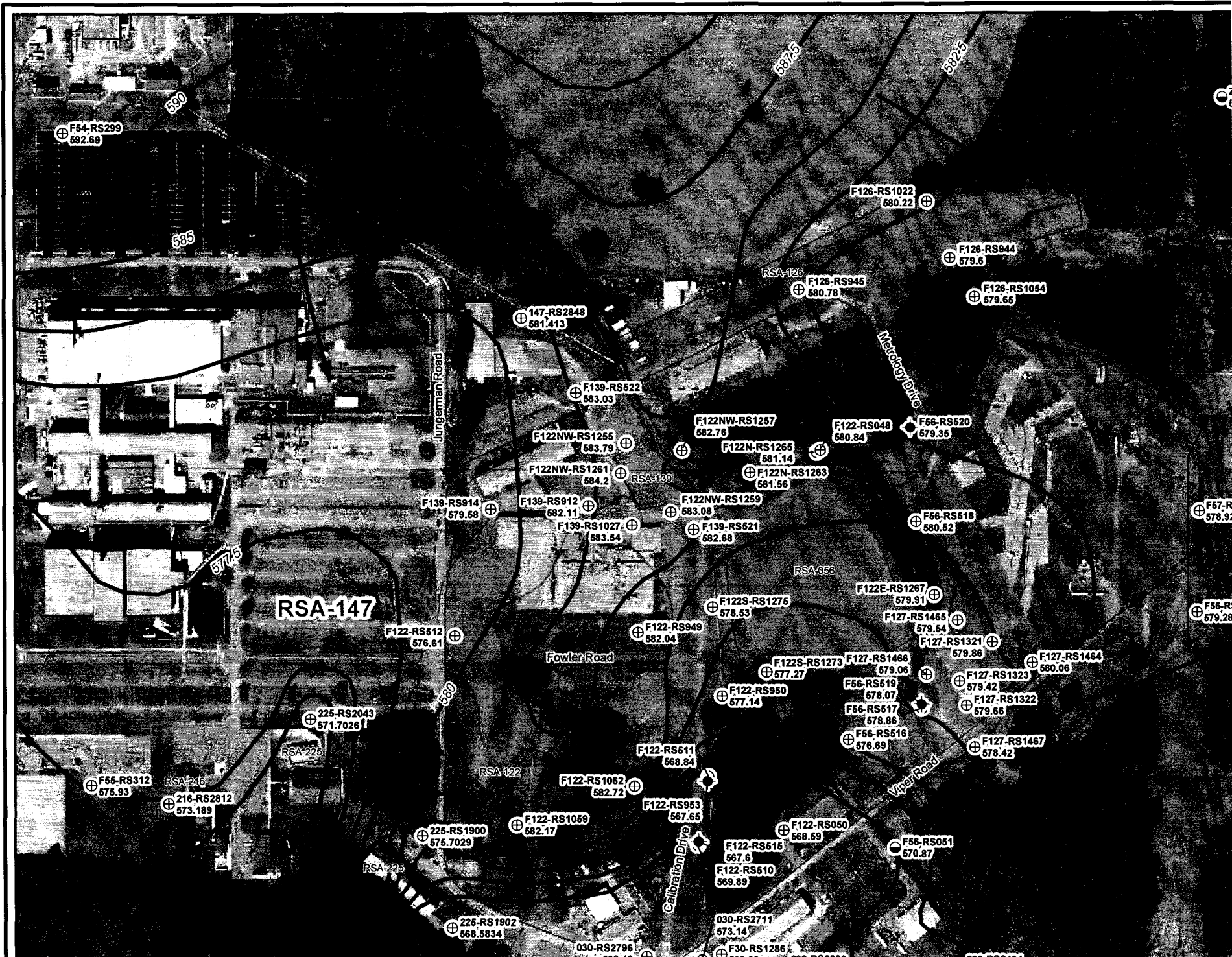


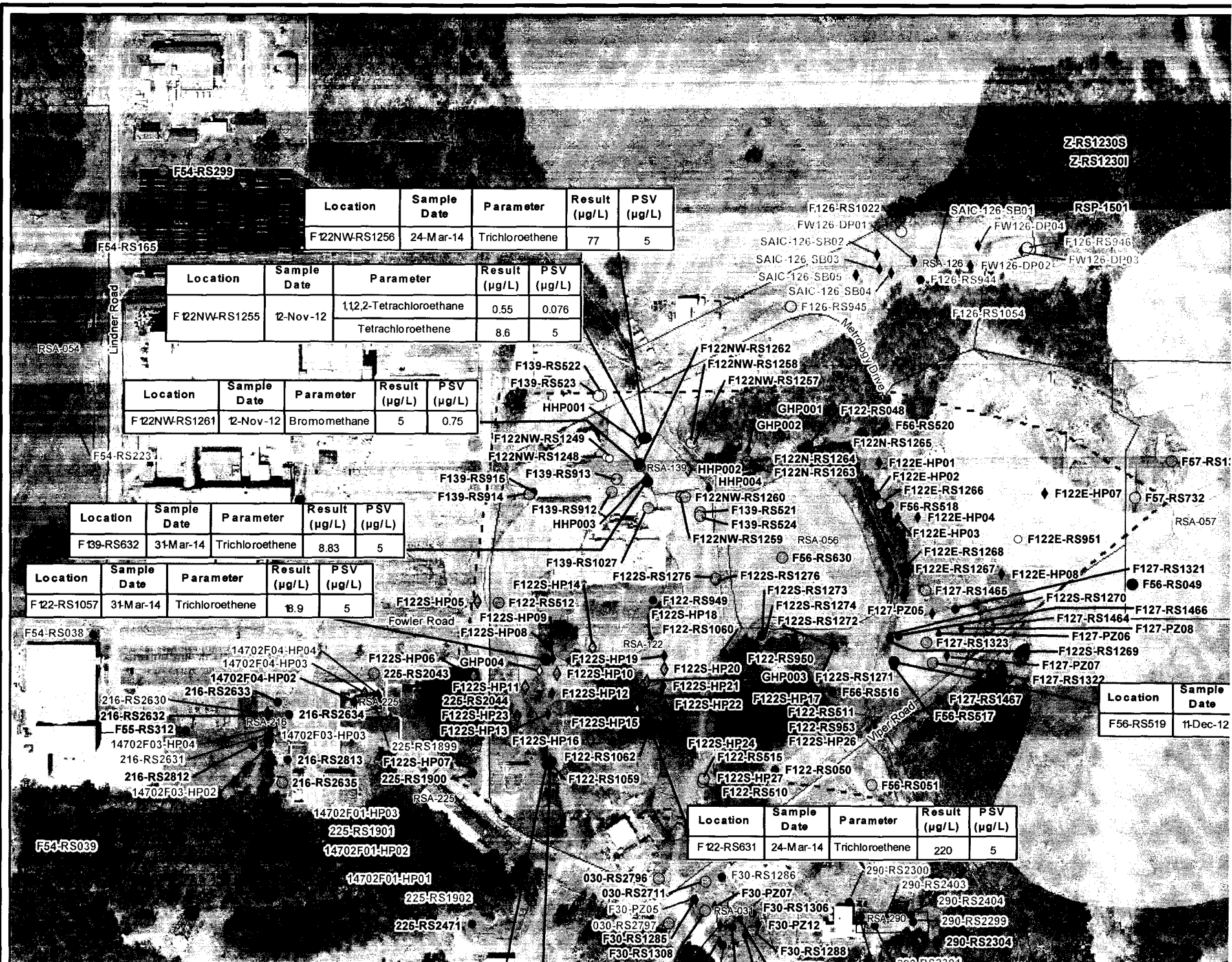
2015 Aerial Photo



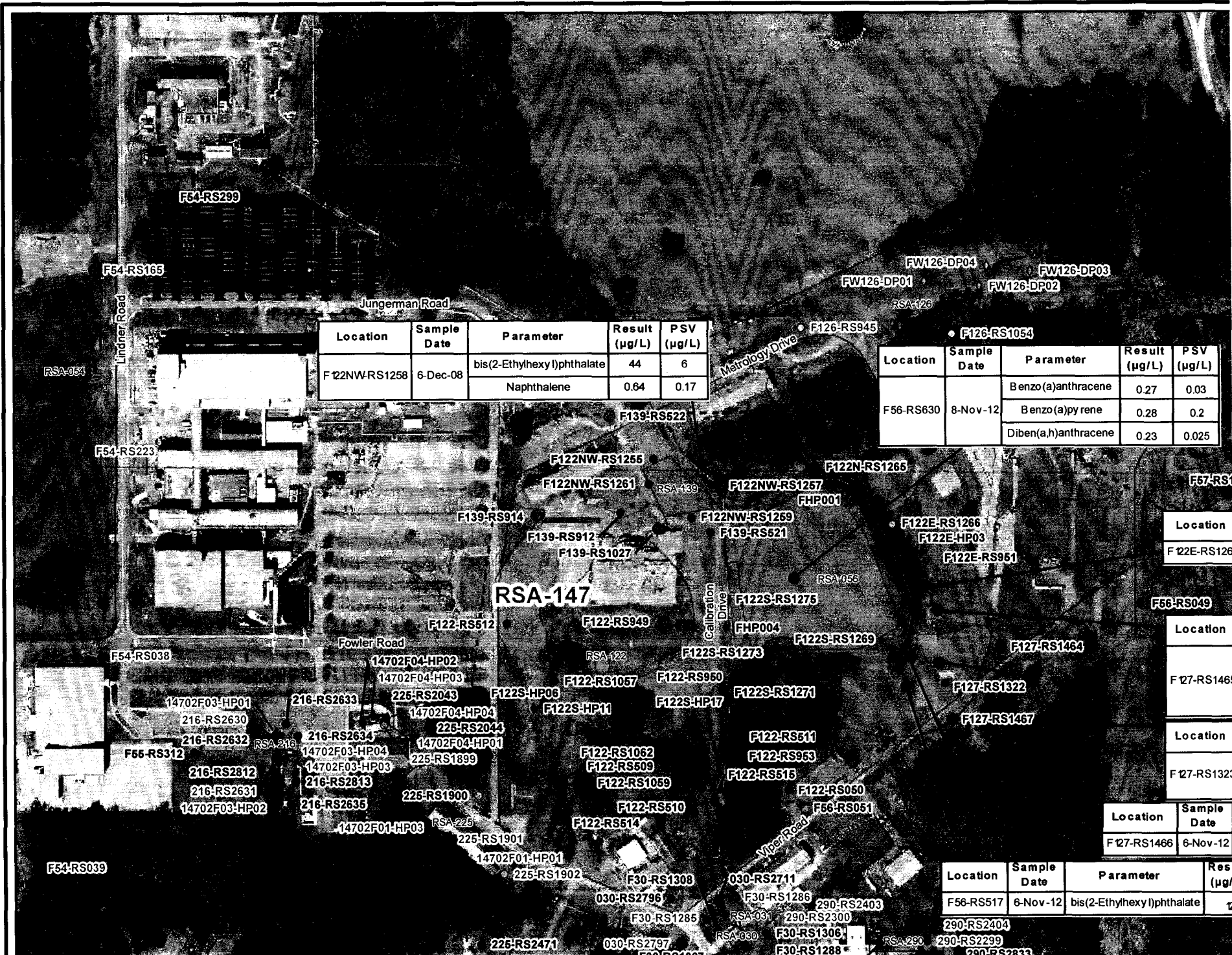






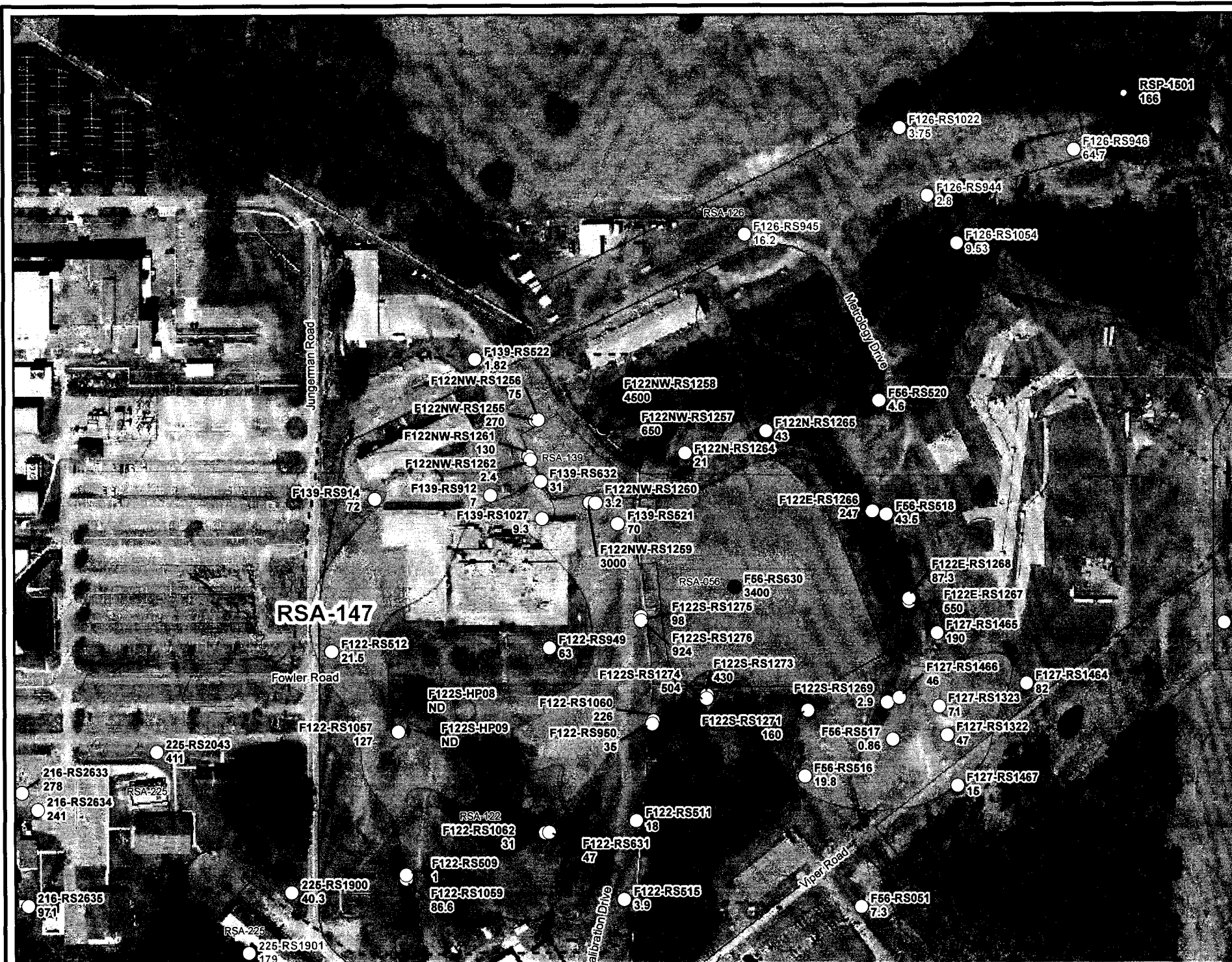




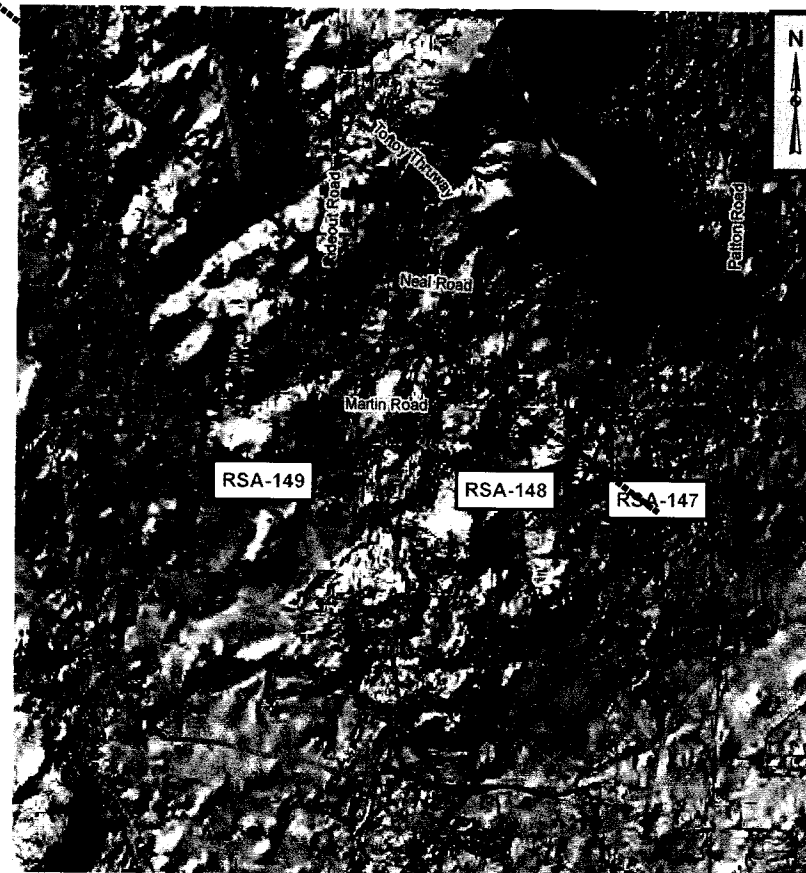
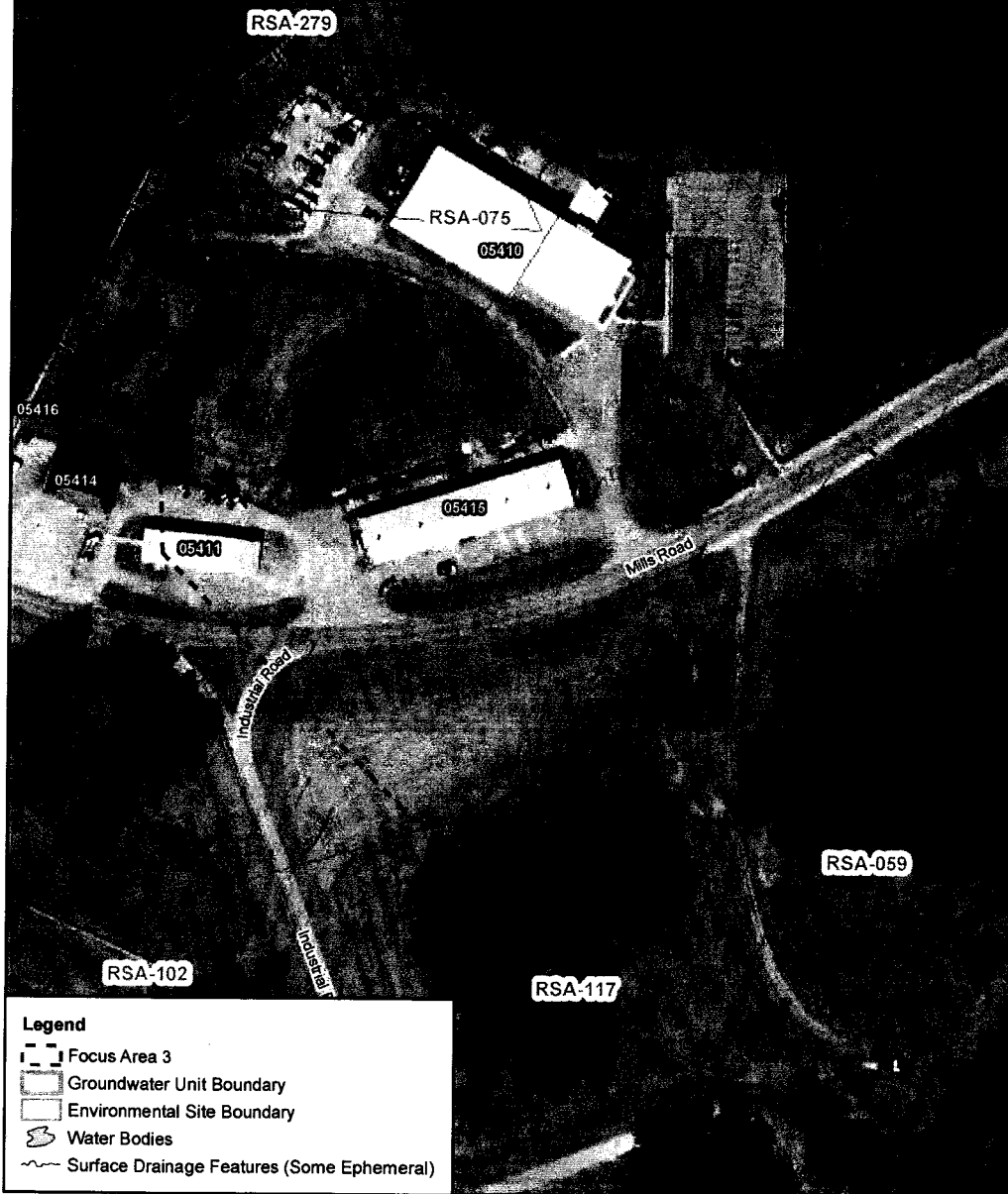








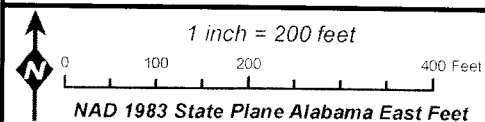
2015 Aerial Photo



**Figure 5-14**

**Focus Area 3  
Site Map**

Redstone Arsenal  
Madison County, Alabama  
Contract No. W91ZLK-09-D-0006



[illegible]



2015 Aerial Photo

030

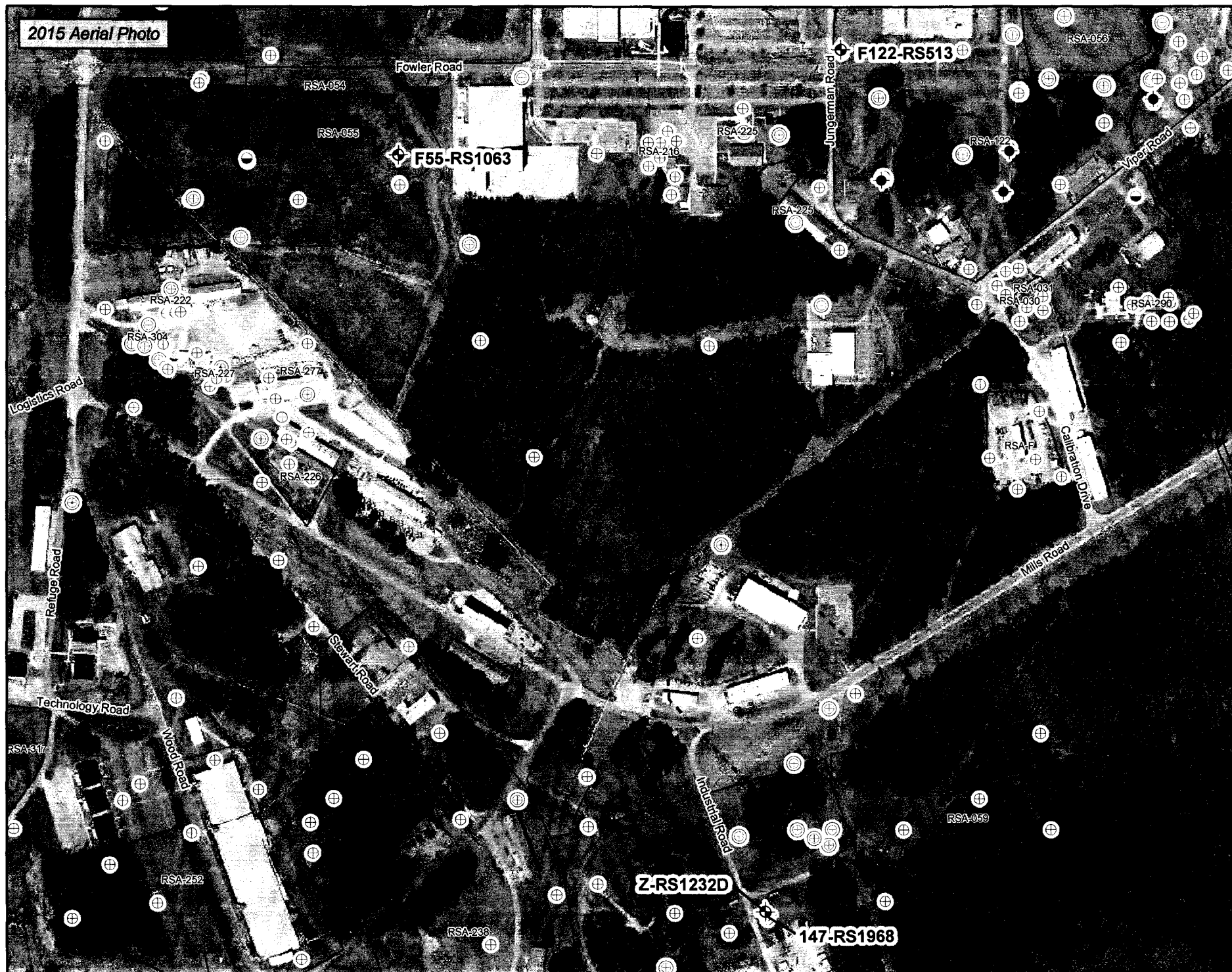


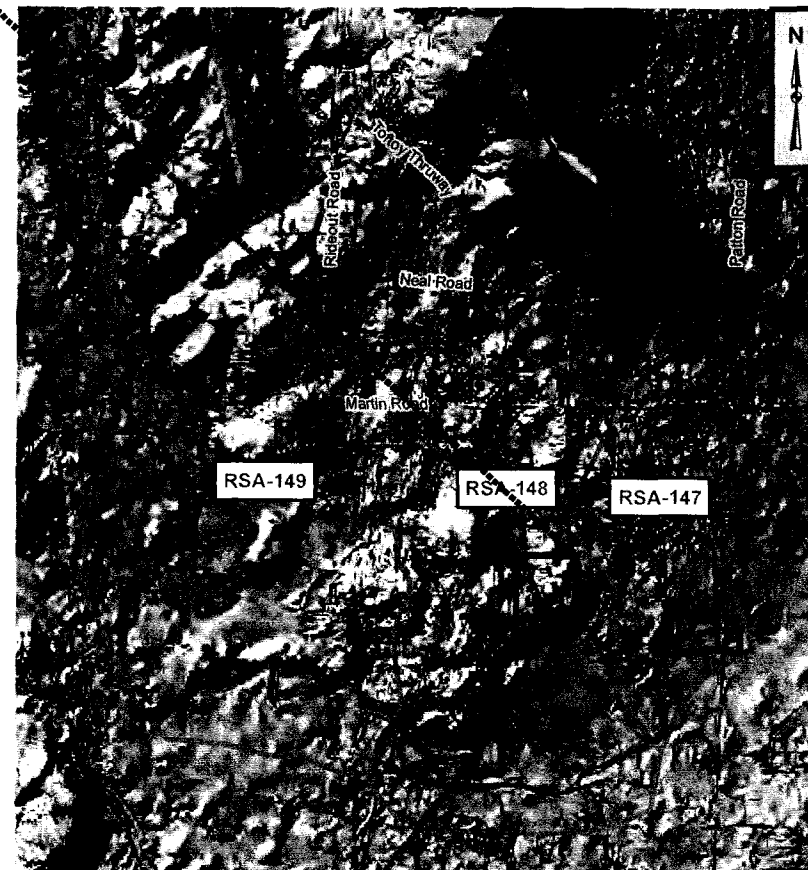
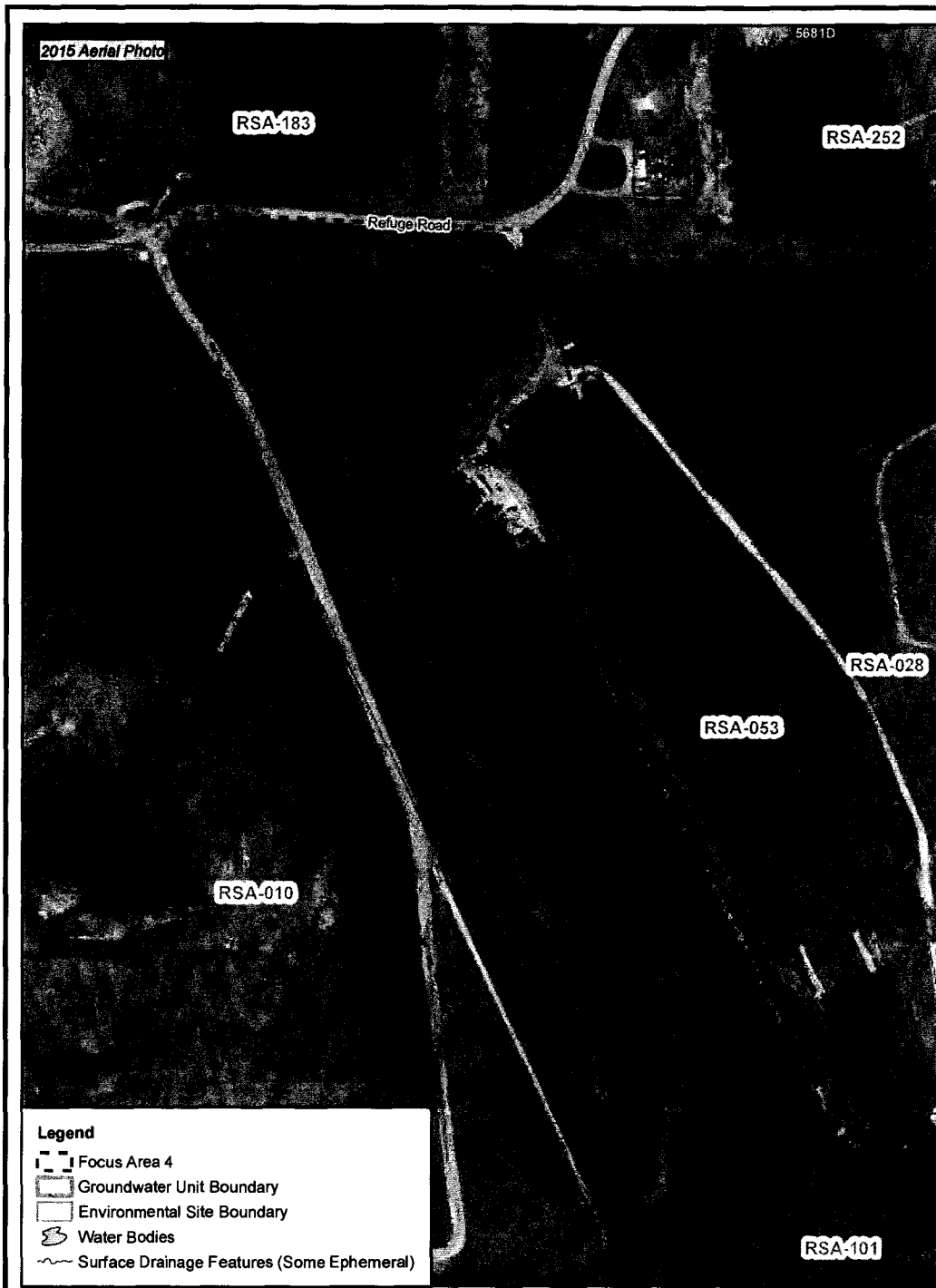






2015 Aerial Photo

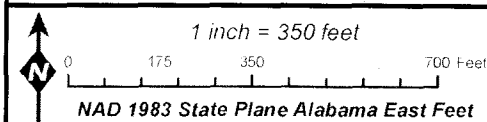


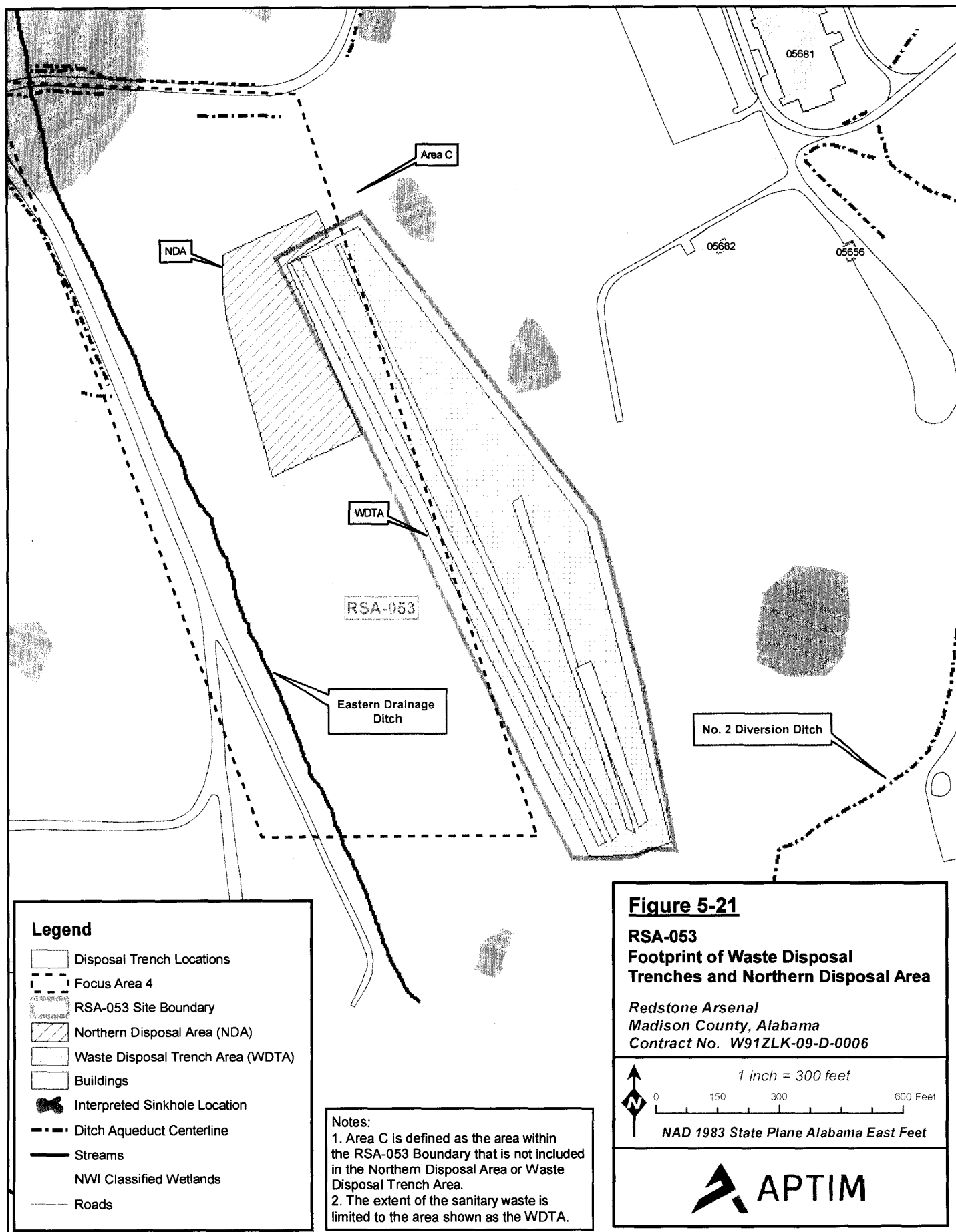


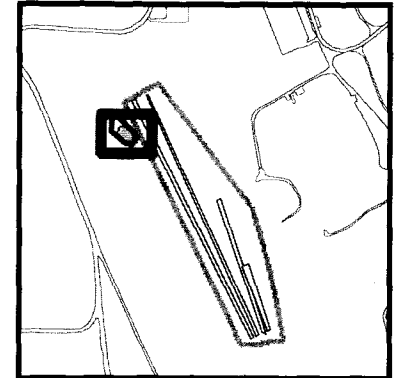
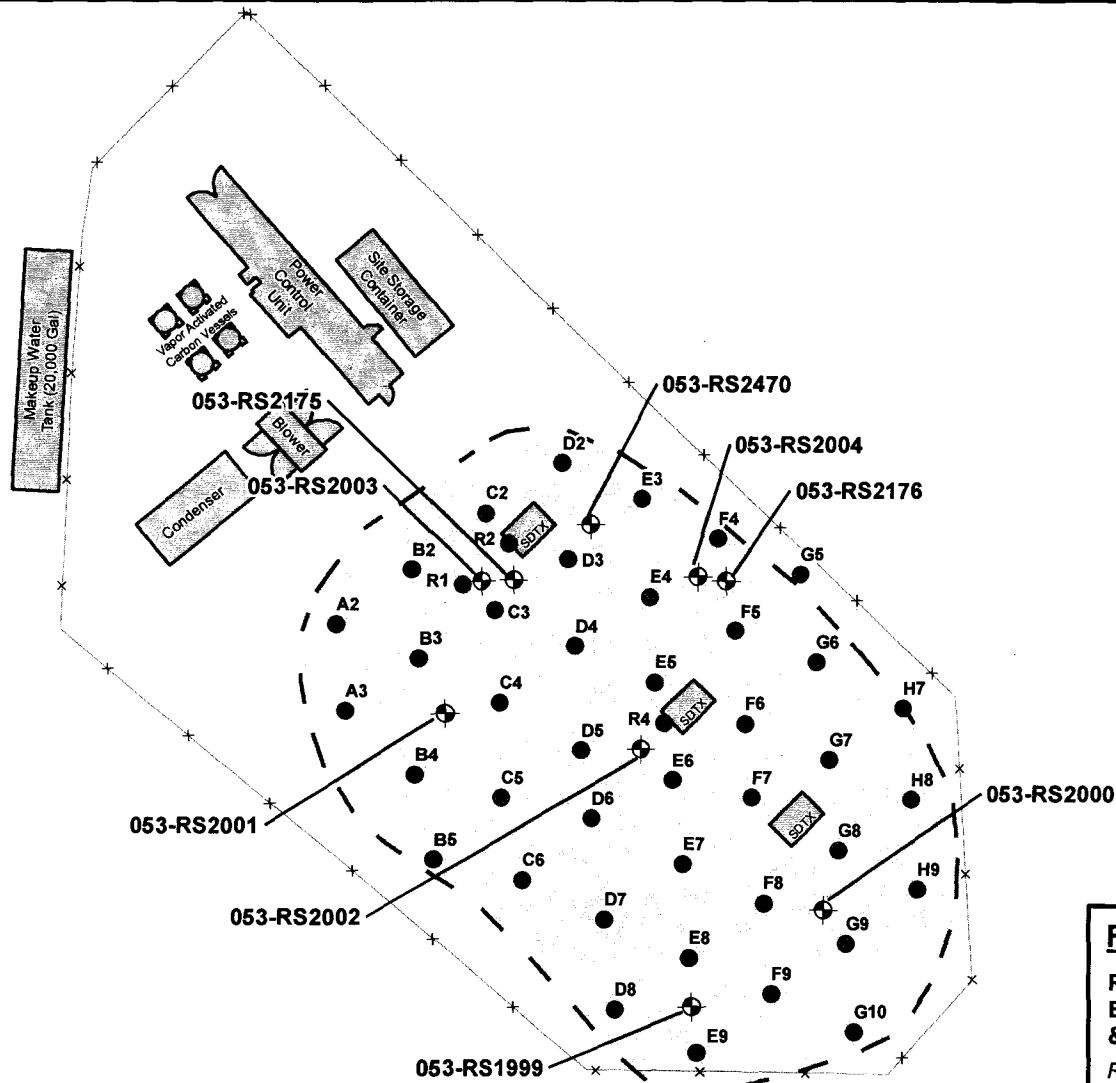
**Figure 5-20**

**Focus Area 4  
Site Map**

Redstone Arsenal  
Madison County, Alabama  
Contract No. W91ZLK-09-D-0006







### Legend

- Electrode/Vapor Recovery Wells
- ⊕ Existing Monitoring Wells
- \*-\*- Security Fence
- ▭ Treatment Area (~7,720 Sq. Ft.)
- ▭ RSA-053 Site Boundary

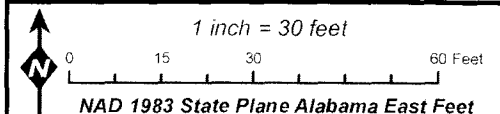
### Notes:

1. Temperature monitoring points are collocated with wells 053-RS1999, 053-RS2000, 053-RS2001, 053-RS2002, 053-RS2175, and 053-RS2176.
2. Due to low pre-remediation groundwater concentrations, well 053-RS2175 was used as an observation well and not for measuring performance against remedial goals.
3. SDTX: step-down transformer

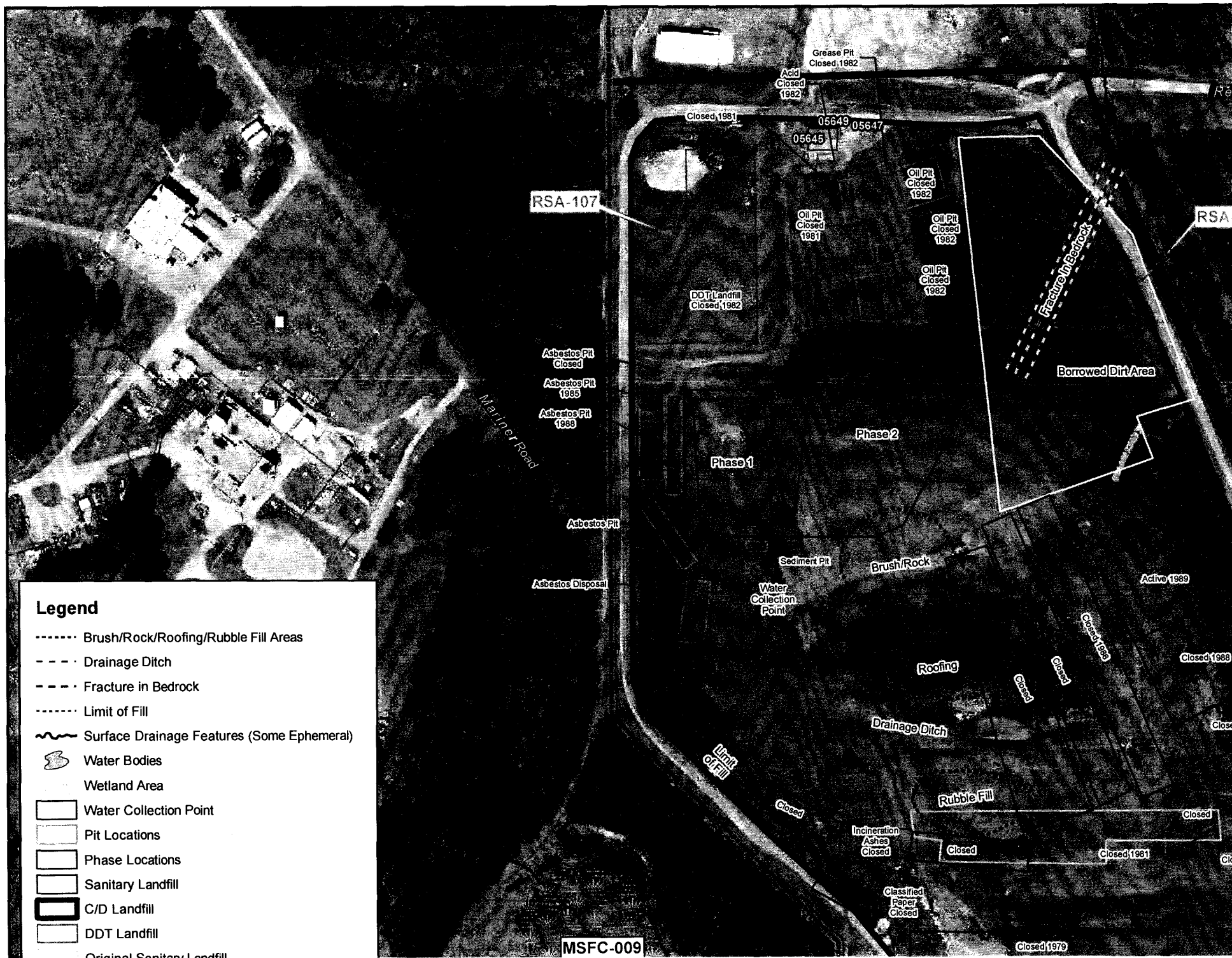
**Figure 5-22**

**RSA-053  
Electrodes, Temperature Monitoring Points,  
& Well Locations within Treatment Area**

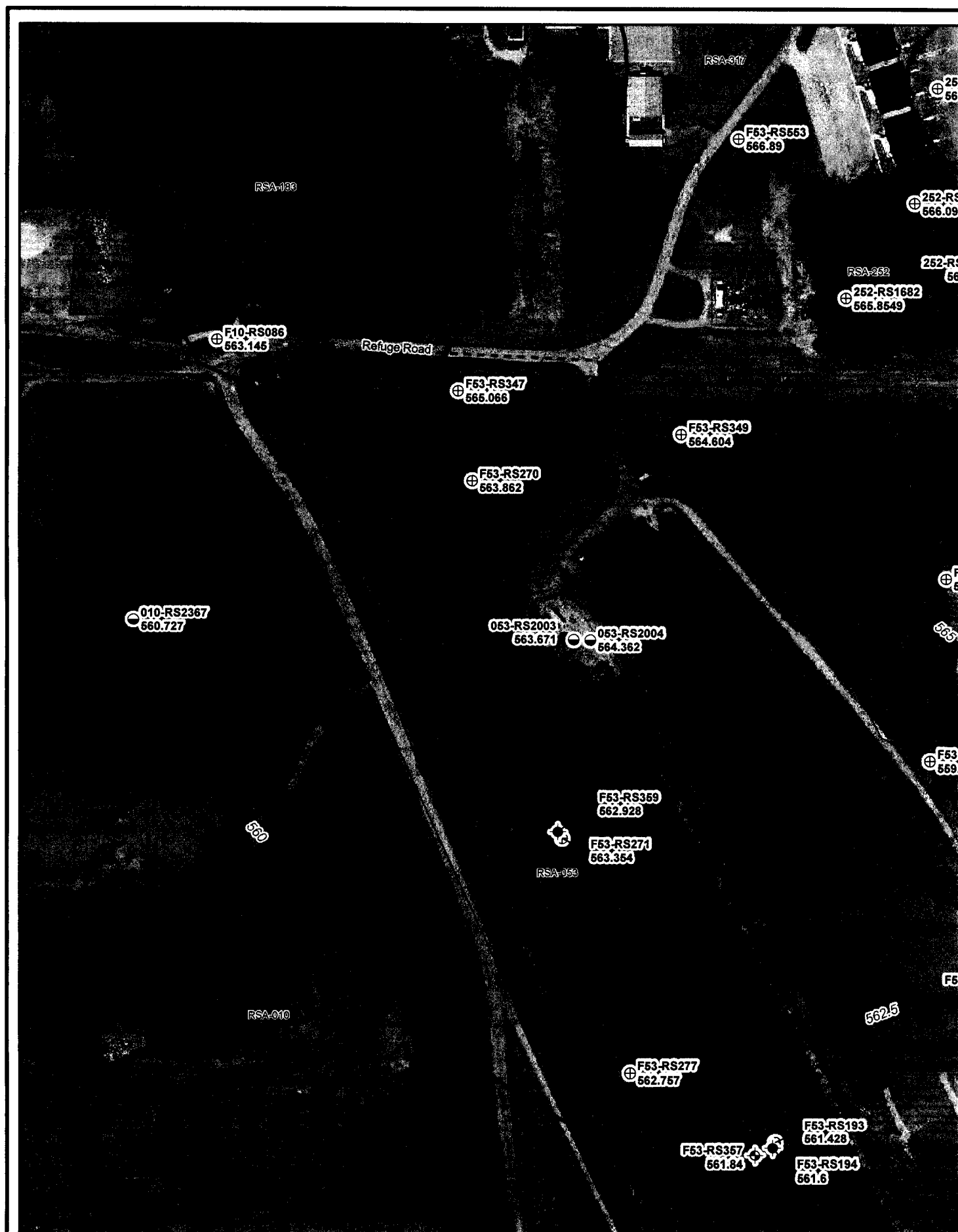
*Redstone Arsenal  
Madison County, Alabama  
Contract No. W91ZLK-09-D-0006*

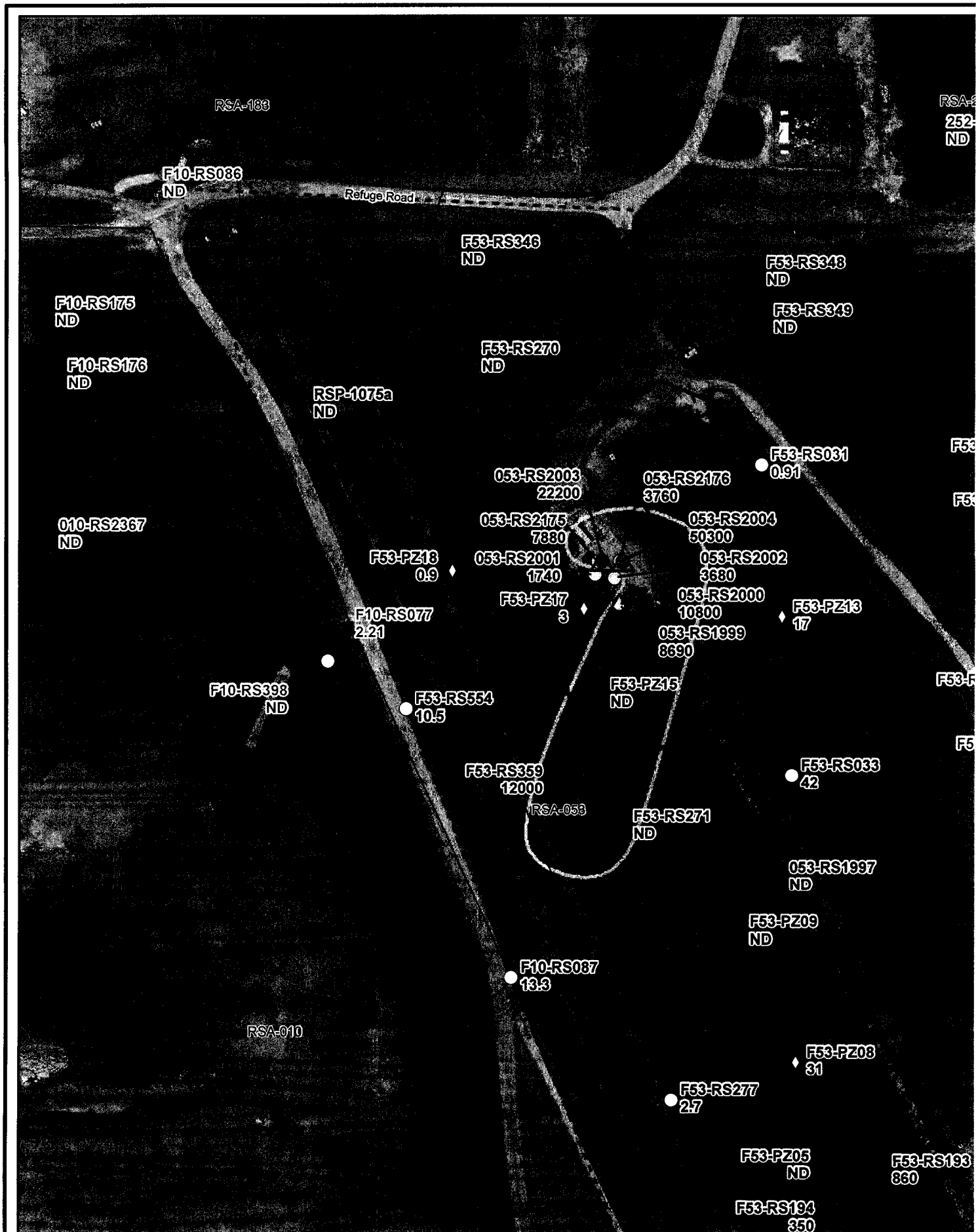




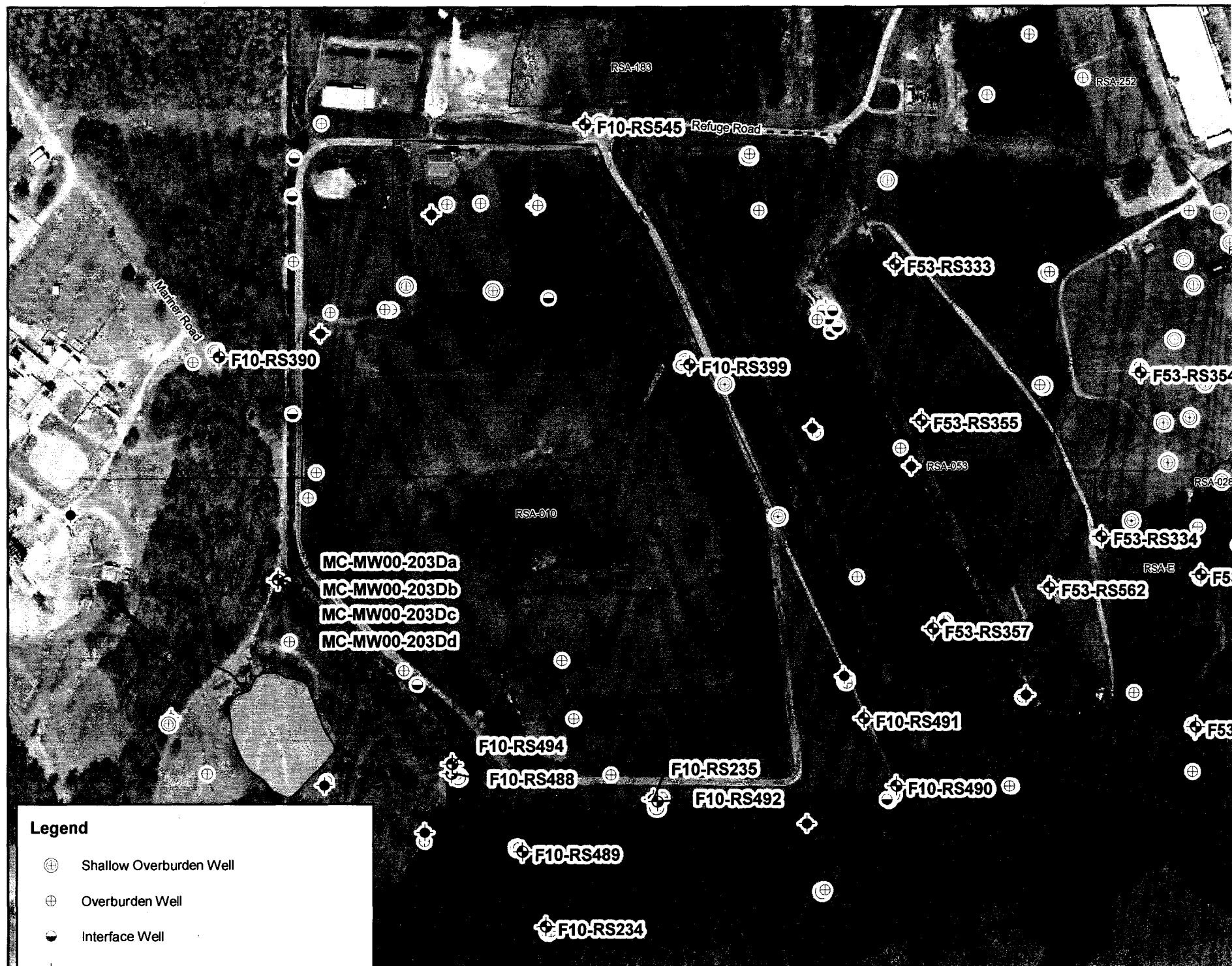












ND - Non-Detect

ND - Non-Detect  
ND\* - a nondetect where the  
DL or RL is greater than  
the PSV but less than 10  
times the PSV

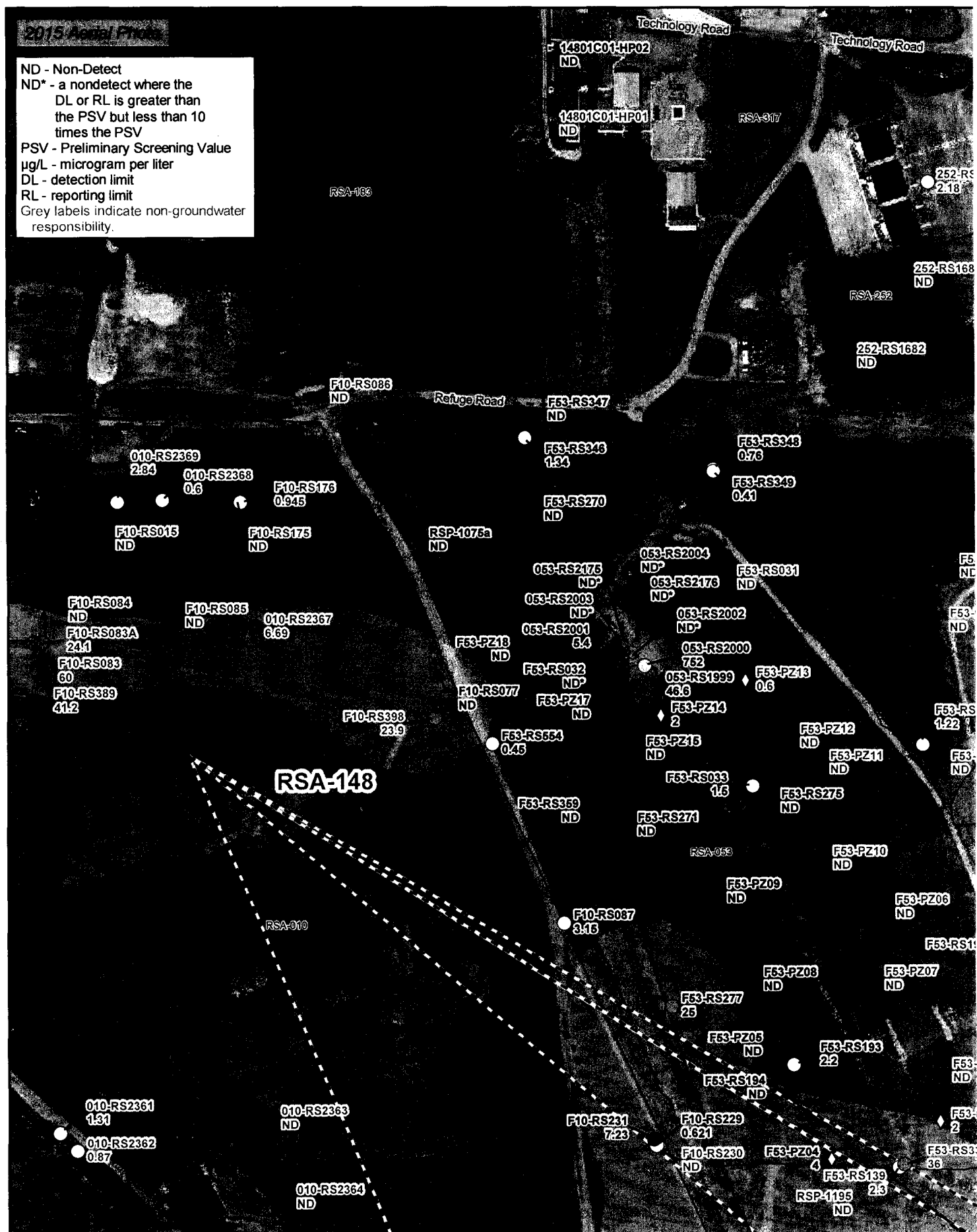
PSV - Preliminary Screening Value

µg/L - microgram per liter

DL - detection limit

RL - reporting limit

Grey labels indicate non-groundwater responsibility.







RSA-183

F10-RS086  
ND

F53-RS347  
ND

F53-RS346  
ND

F53-RS349  
ND

F10-RS175  
0.744

F10-RS176  
ND

RSP-1075a  
ND

010-RS2367  
ND

F53-PZ18  
0.7

053-RS2175  
1100

053-RS2176  
290

053-RS2003  
82

053-RS2004  
6160

053-RS2001  
ND

053-RS2002  
43.5

F53-PZ17  
ND

053-RS2000  
271

F53-PZ13  
ND

F10-RS077  
ND

F10-RS398  
ND

F53-RS534  
ND

053-RS1999  
602

F53-PZ15  
ND

RSA-053

F53-RS271  
ND

F53-PZ12  
ND

F53-RS033  
ND

F53-RS275  
ND

F53-PZ1  
ND

RSA-010

F10-RS087  
ND

F53-PZ09  
ND

F53-RS277  
ND

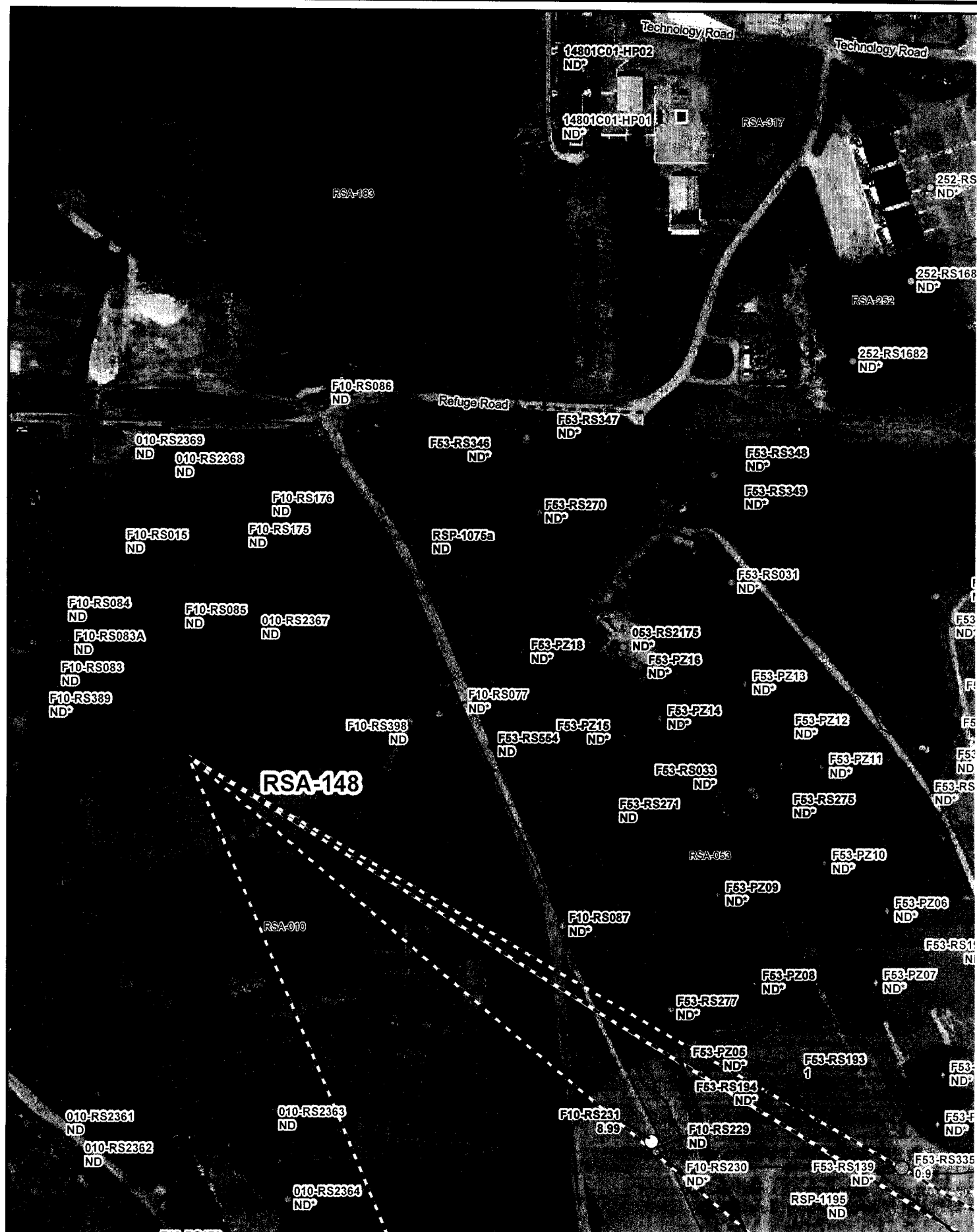
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ND

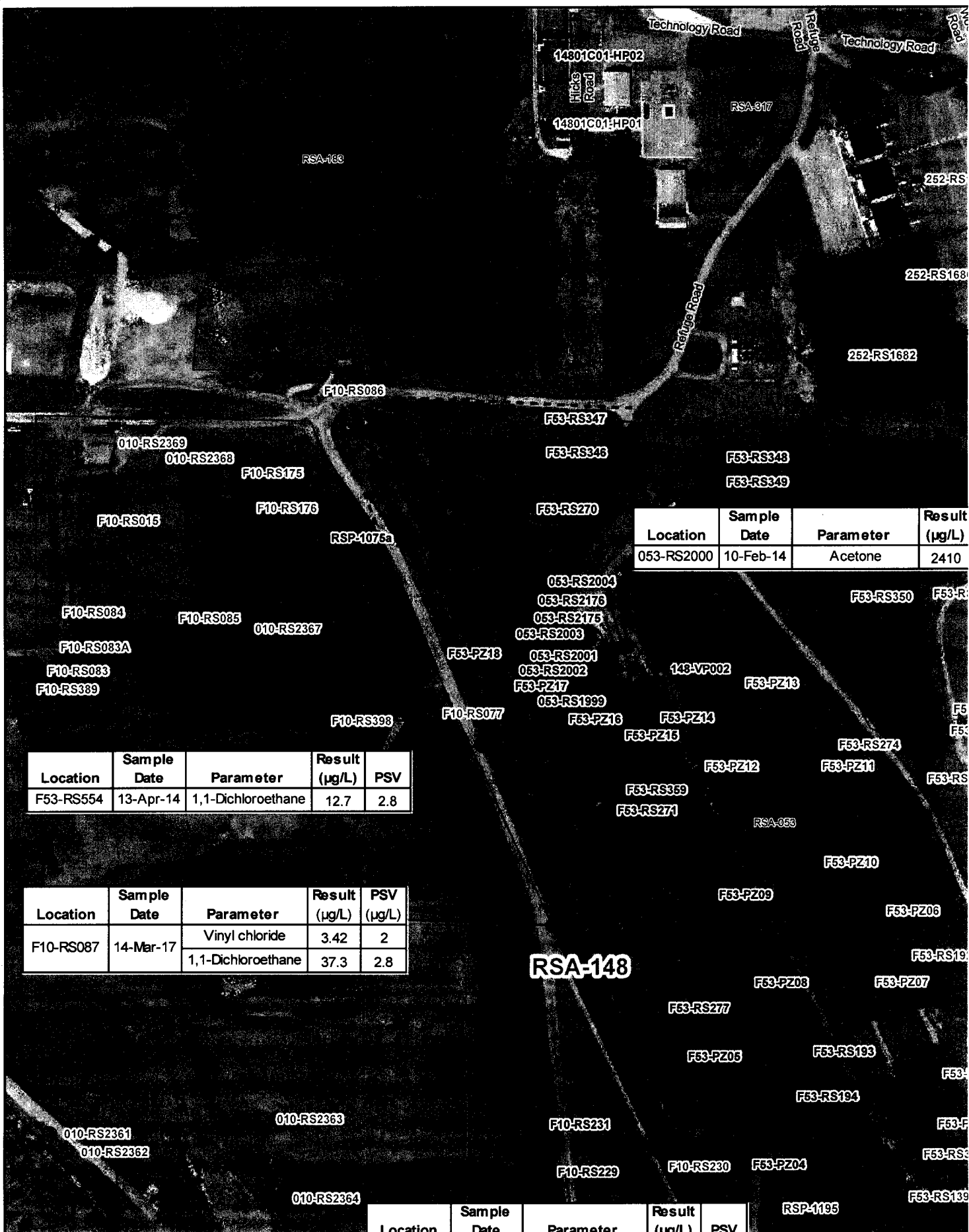
F53-PZ05  
ND

F53-RS193  
ND









Location	Sample Date	Parameter	Result (µg/L)	PSV
F53-RS554	13-Apr-14	1,1-Dichloroethane	12.7	2.8

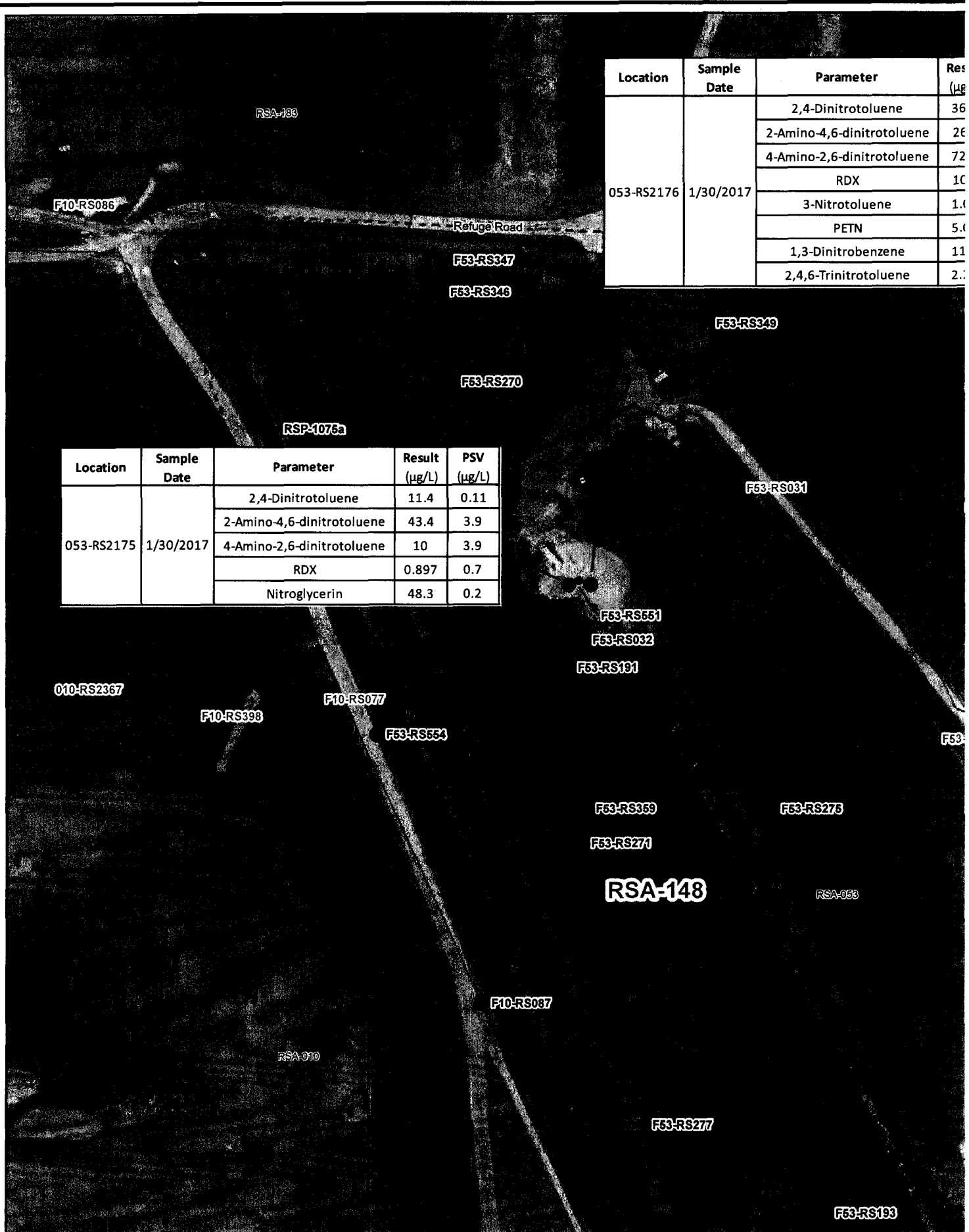
Location	Sample Date	Parameter	Result (µg/L)	PSV (µg/L)
F10-RS087	14-Mar-17	Vinyl chloride	3.42	2
		1,1-Dichloroethane	37.3	2.8

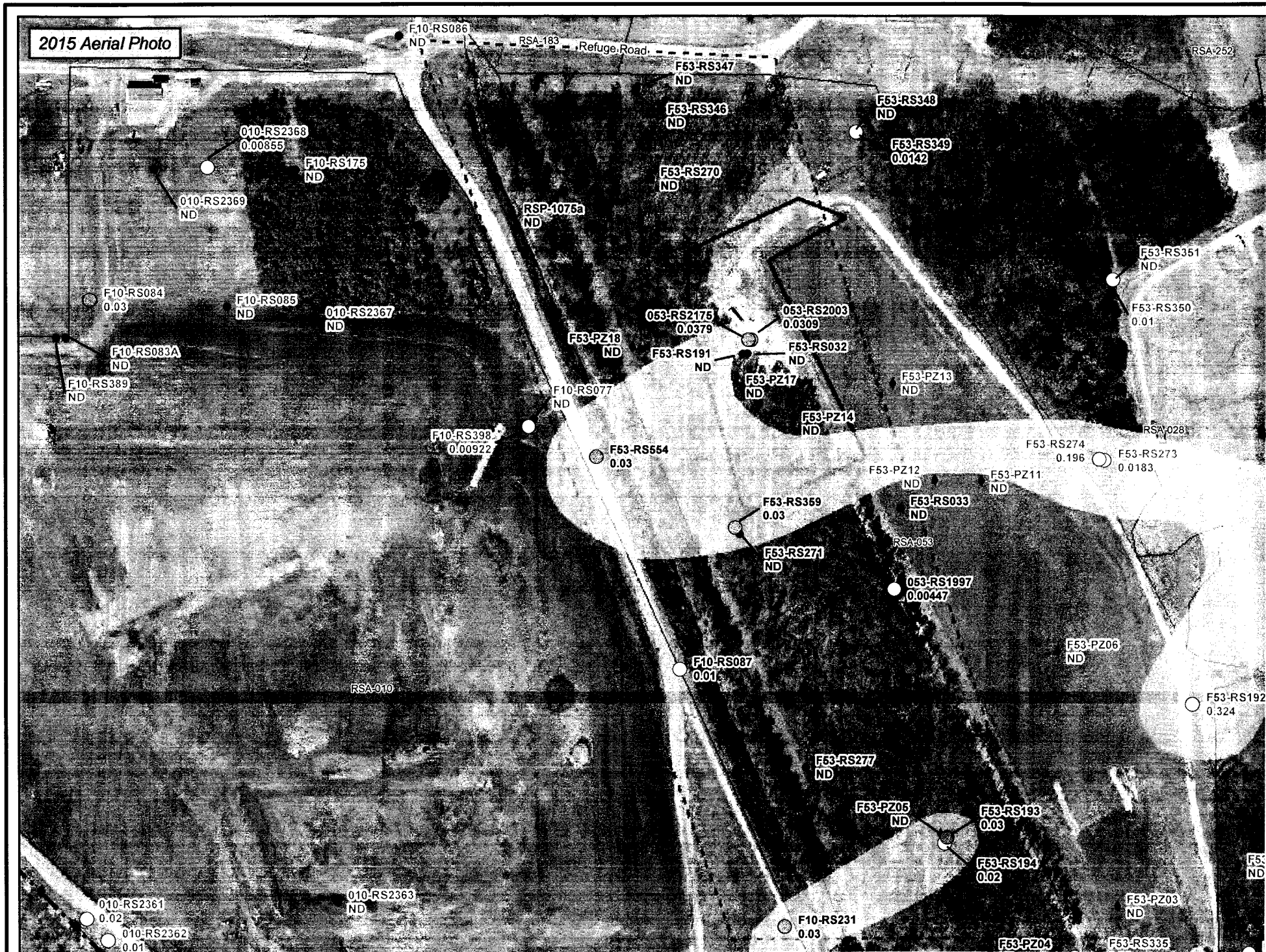
Location	Sample Date	Parameter	Result (µa/L)	PSV
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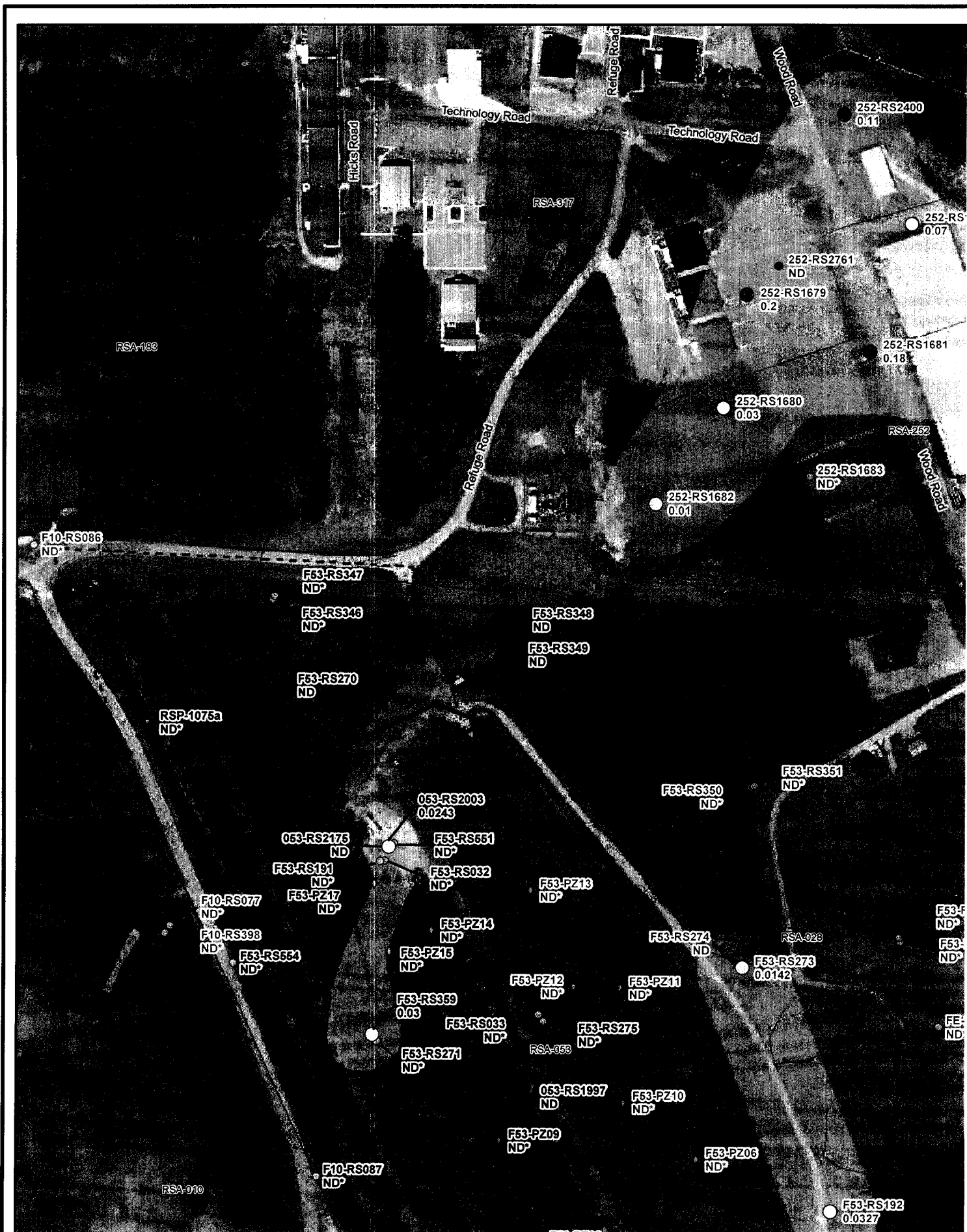
Location	Sample Date	Parameter	Res (µg/L)
053-RS2176	1/30/2017	2,4-Dinitrotoluene	36
		2-Amino-4,6-dinitrotoluene	26
		4-Amino-2,6-dinitrotoluene	72
		RDX	10
		3-Nitrotoluene	1.0
		PETN	5.0
		1,3-Dinitrobenzene	11
		2,4,6-Trinitrotoluene	2.0

Location	Sample Date	Parameter	Result (µg/L)	PSV (µg/L)
053-RS2175	1/30/2017	2,4-Dinitrotoluene	11.4	0.11
		2-Amino-4,6-dinitrotoluene	43.4	3.9
		4-Amino-2,6-dinitrotoluene	10	3.9
		RDX	0.897	0.7
		Nitroglycerin	48.3	0.2

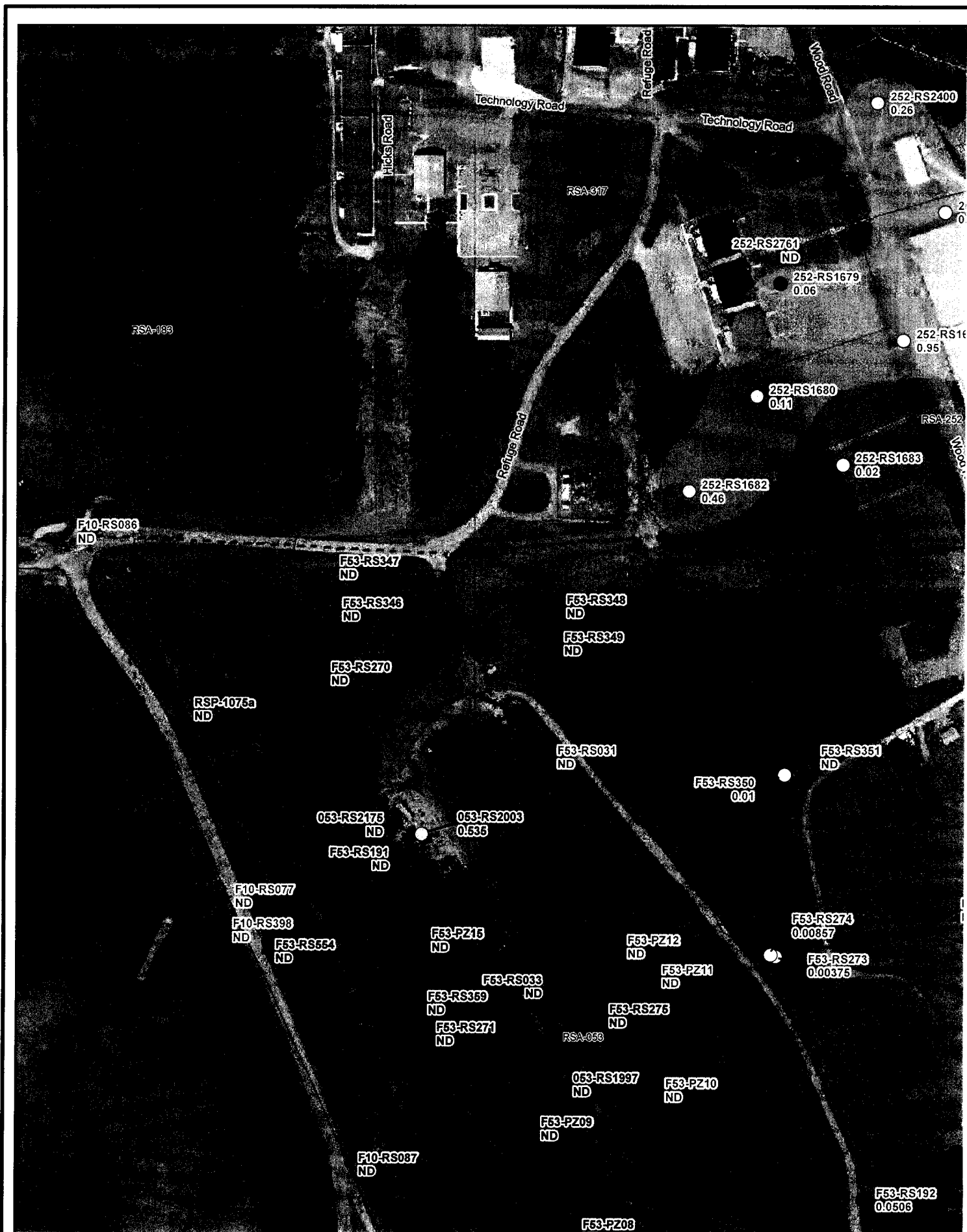




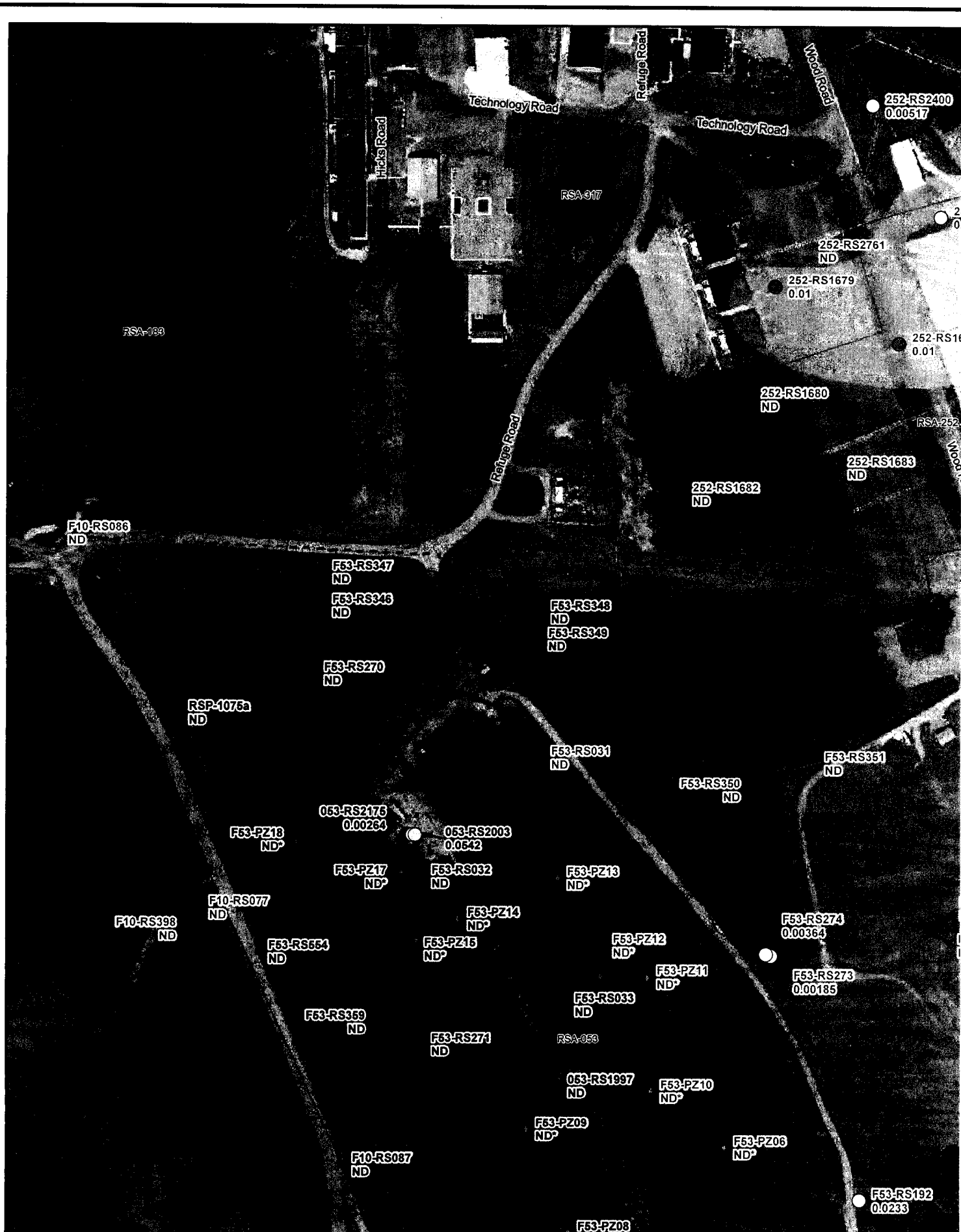


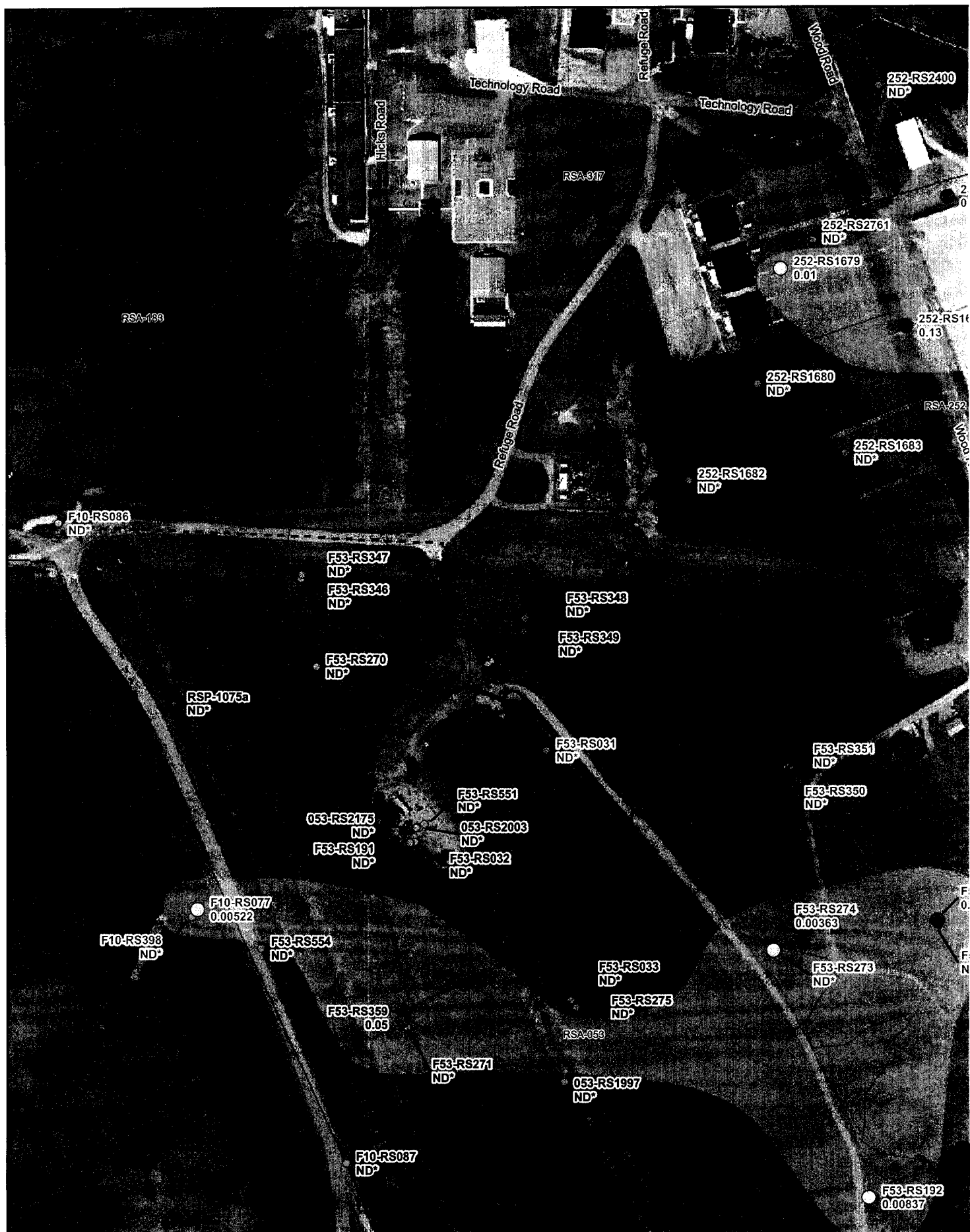




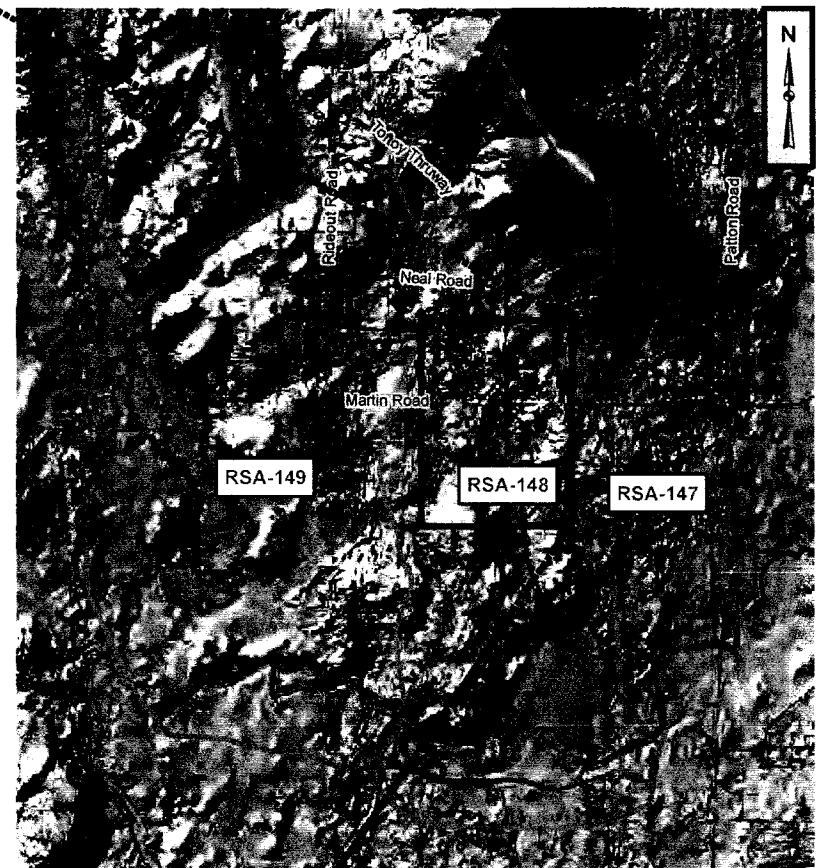








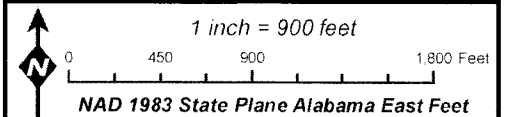


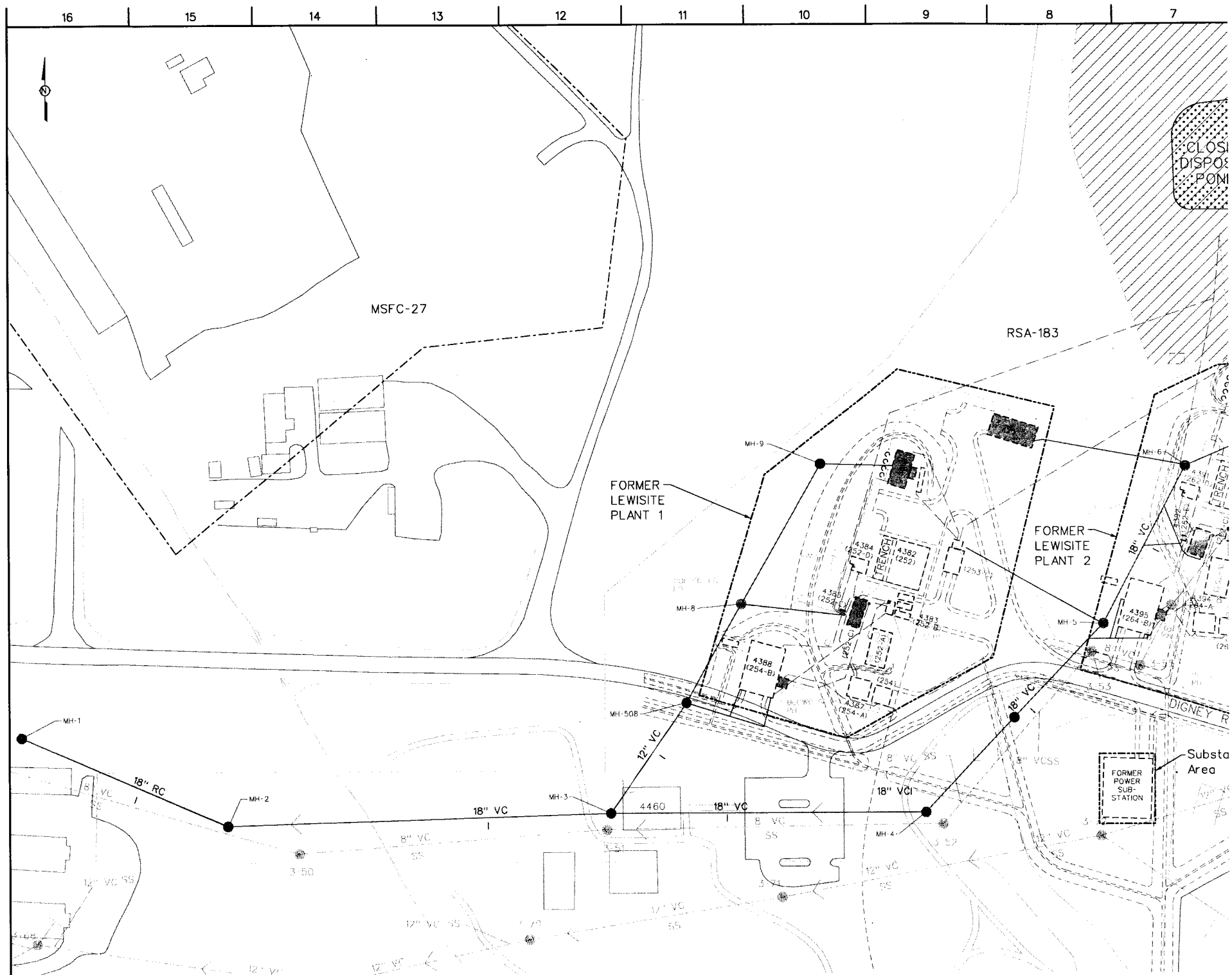


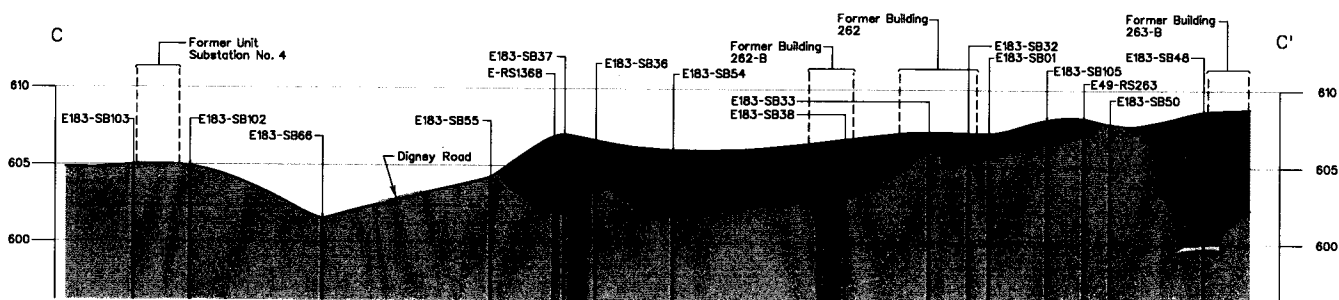
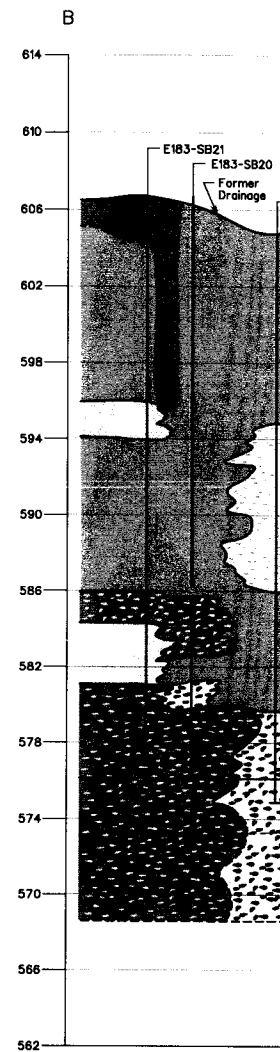
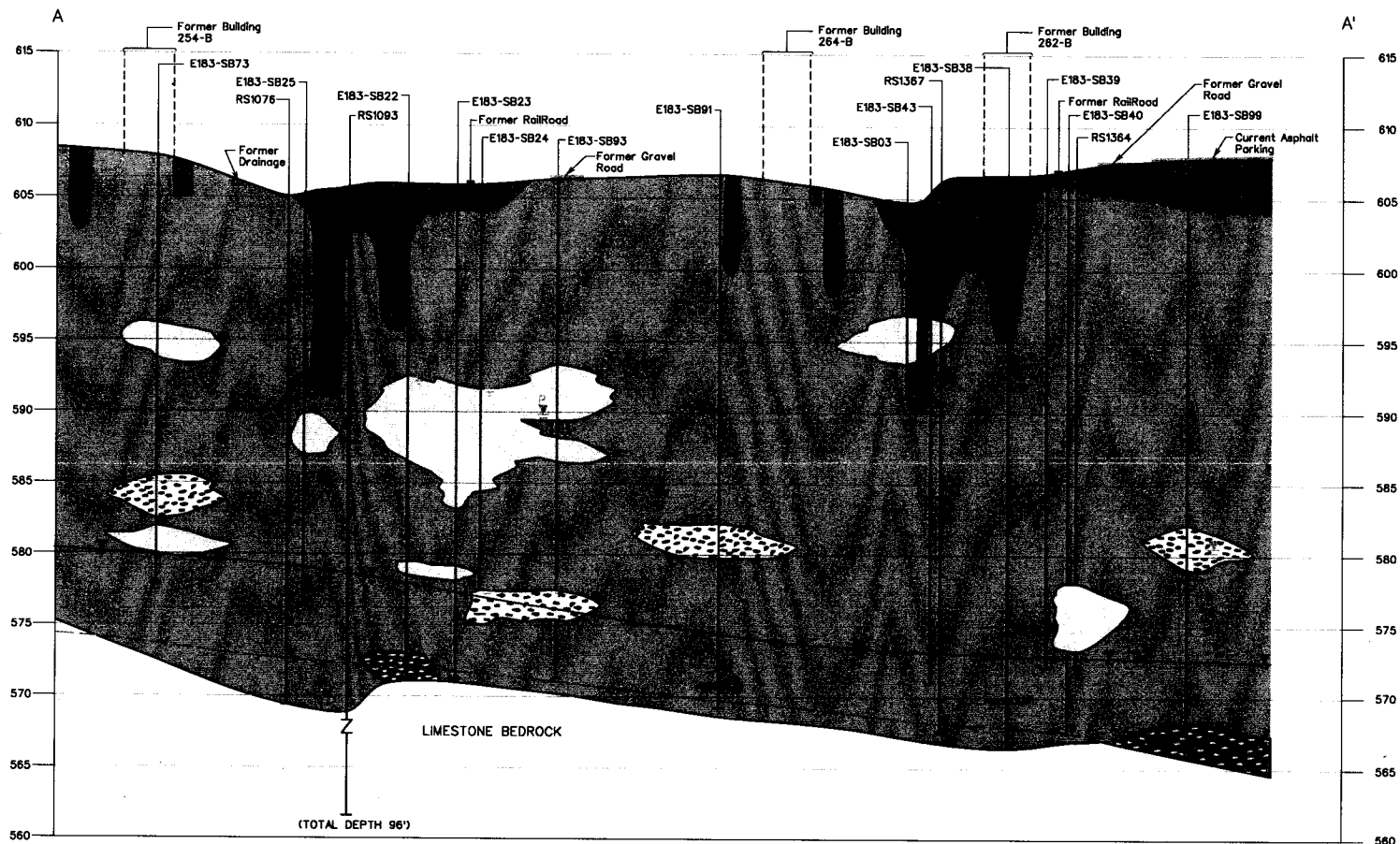
**Figure 5-43**

**Focus Area 5  
Site Map**

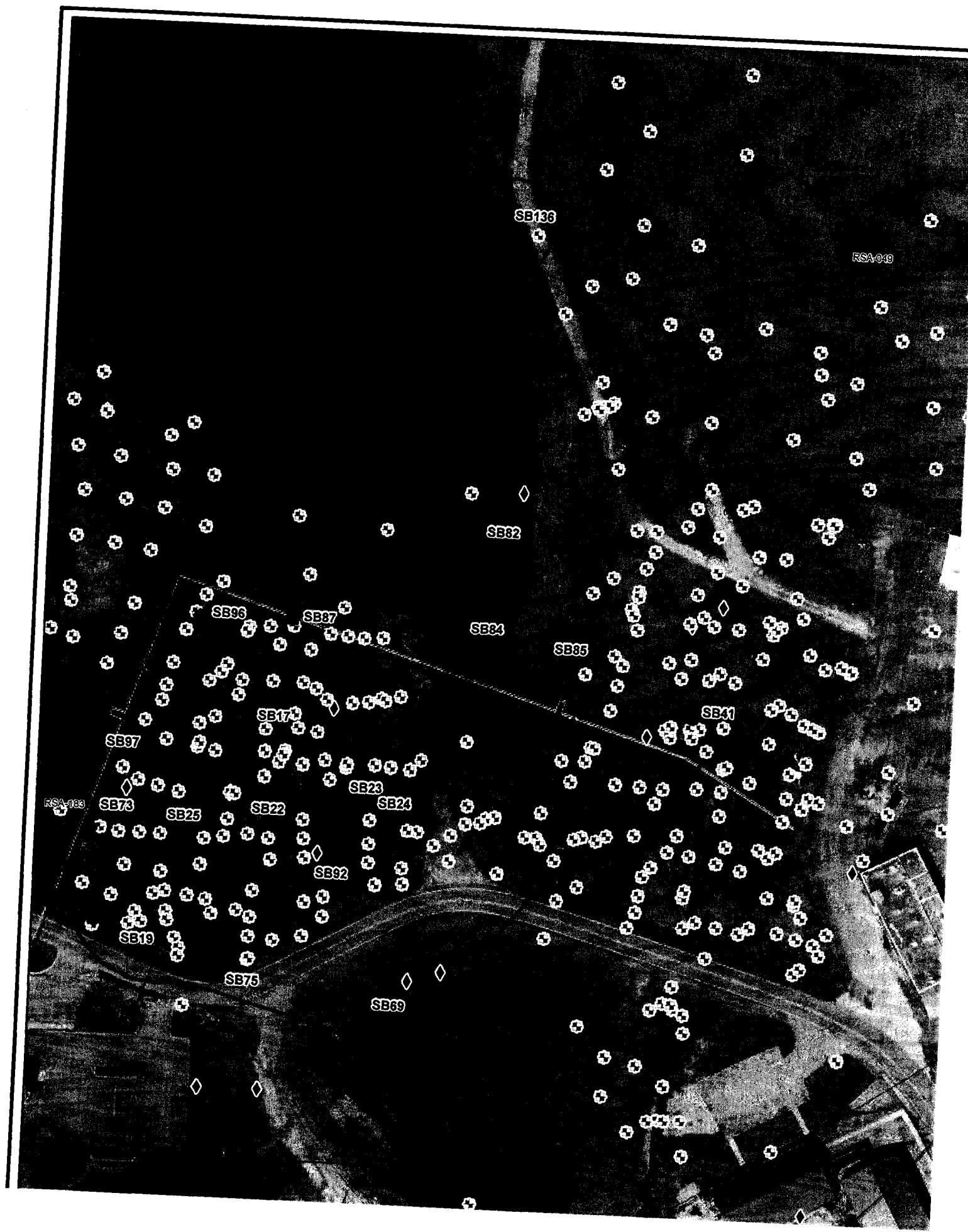
*Redstone Arsenal  
Madison County, Alabama  
Contract No. W91ZLK-09-D-0006*



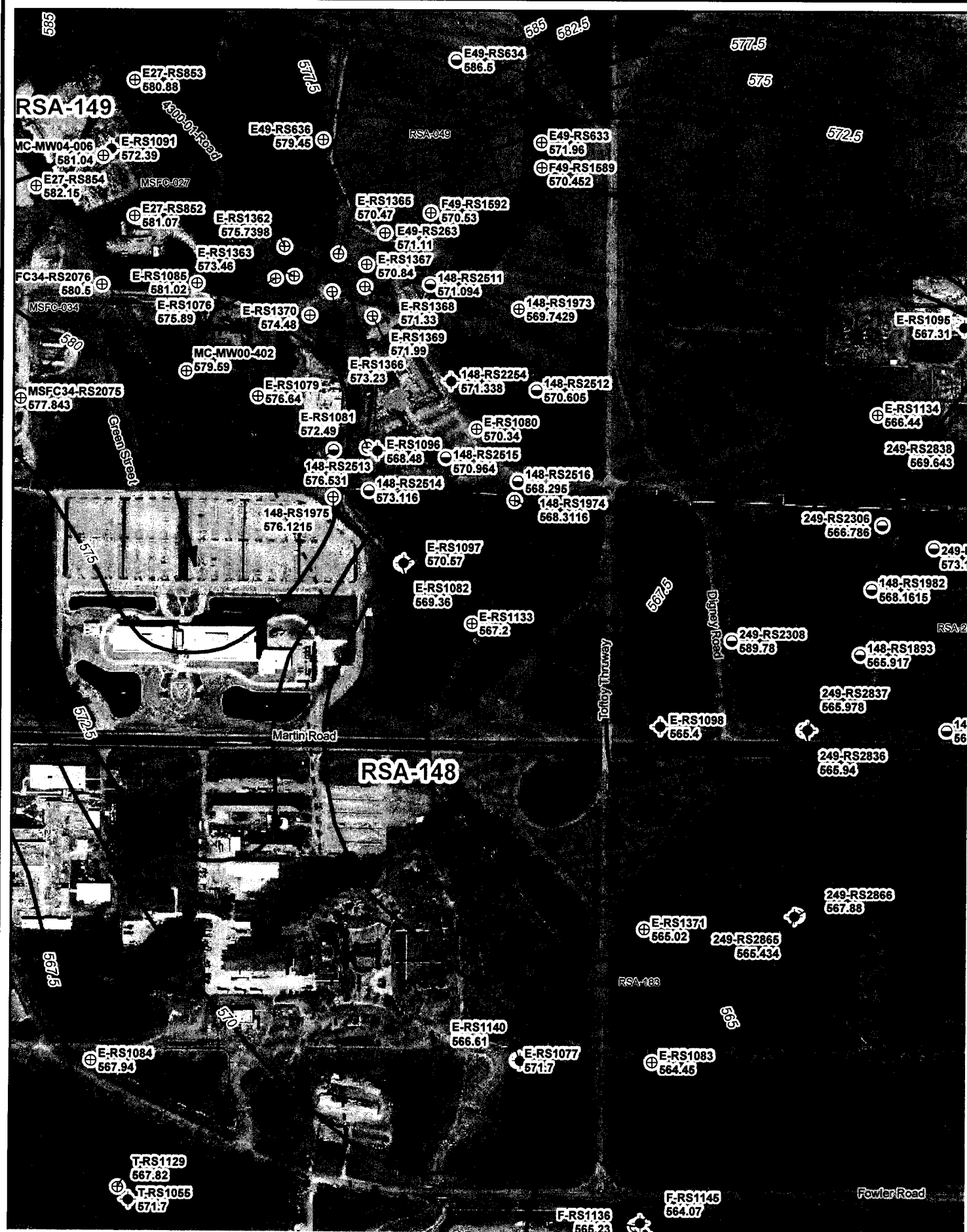




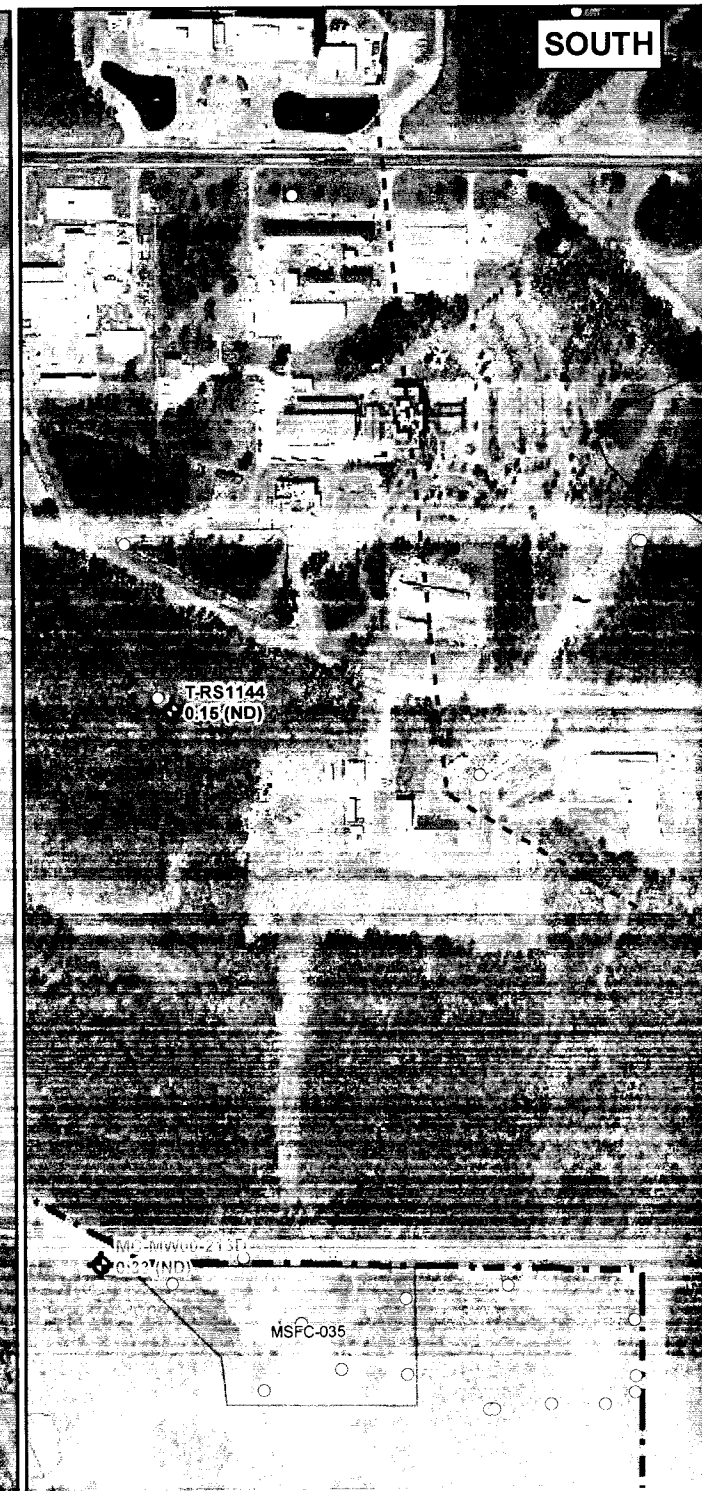
Plant No. 1













See Figure 5-50

RSA-148

249-PZ11  
2.56  
148-RS198  
407  
249-PZ22  
0.812  
148-RS1833  
44  
249-PZ24  
4.56  
14801A-HP05  
0.69  
249-R  
417

E-RS1133  
0.72

E-HP27  
0.52

E-HP32

Martin Road

E-HP09

E-RS1033  
3.15

249-RS2836  
415

E-HP39

E-HP29  
12

RSA-138

E-RS0271  
2.10

249-RS28

E-HP30

E-HP08

E-RS1084

E-RS1077

E-RS1140  
0.523

E-RS1033  
7.37

Fowler Road

E-HP26

T-RS1129  
T-RS1055

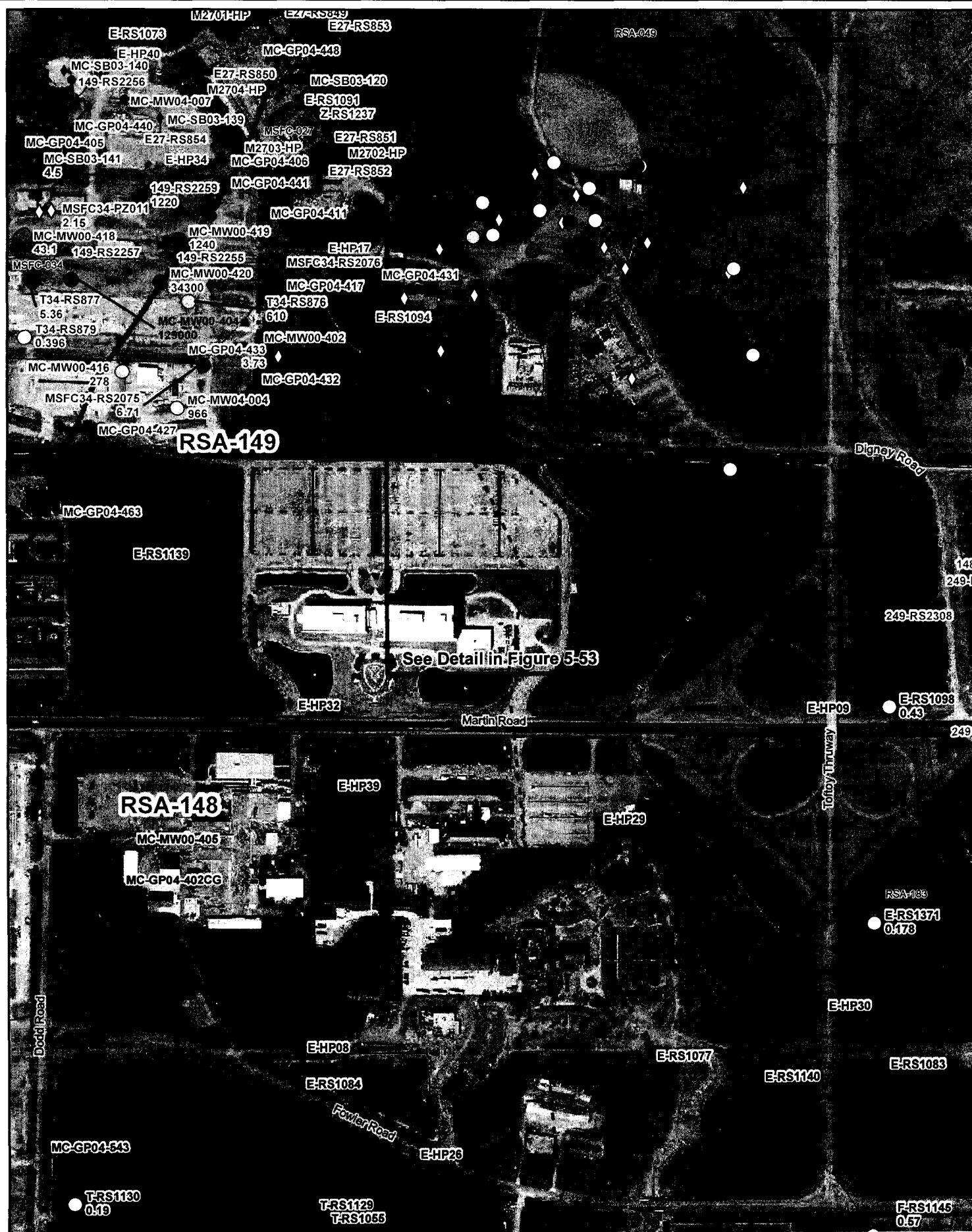
F-RS1145  
23

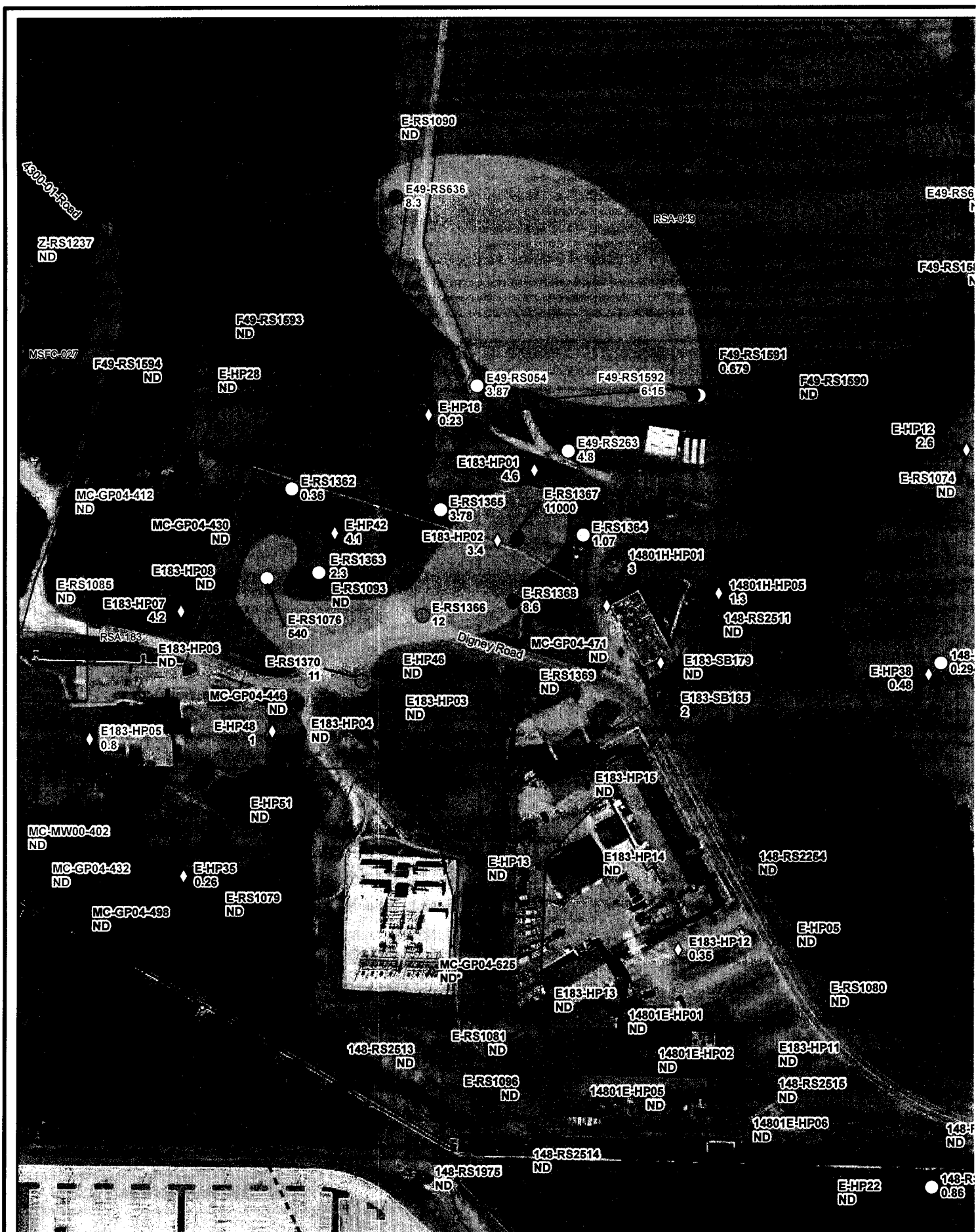
E-RS1133

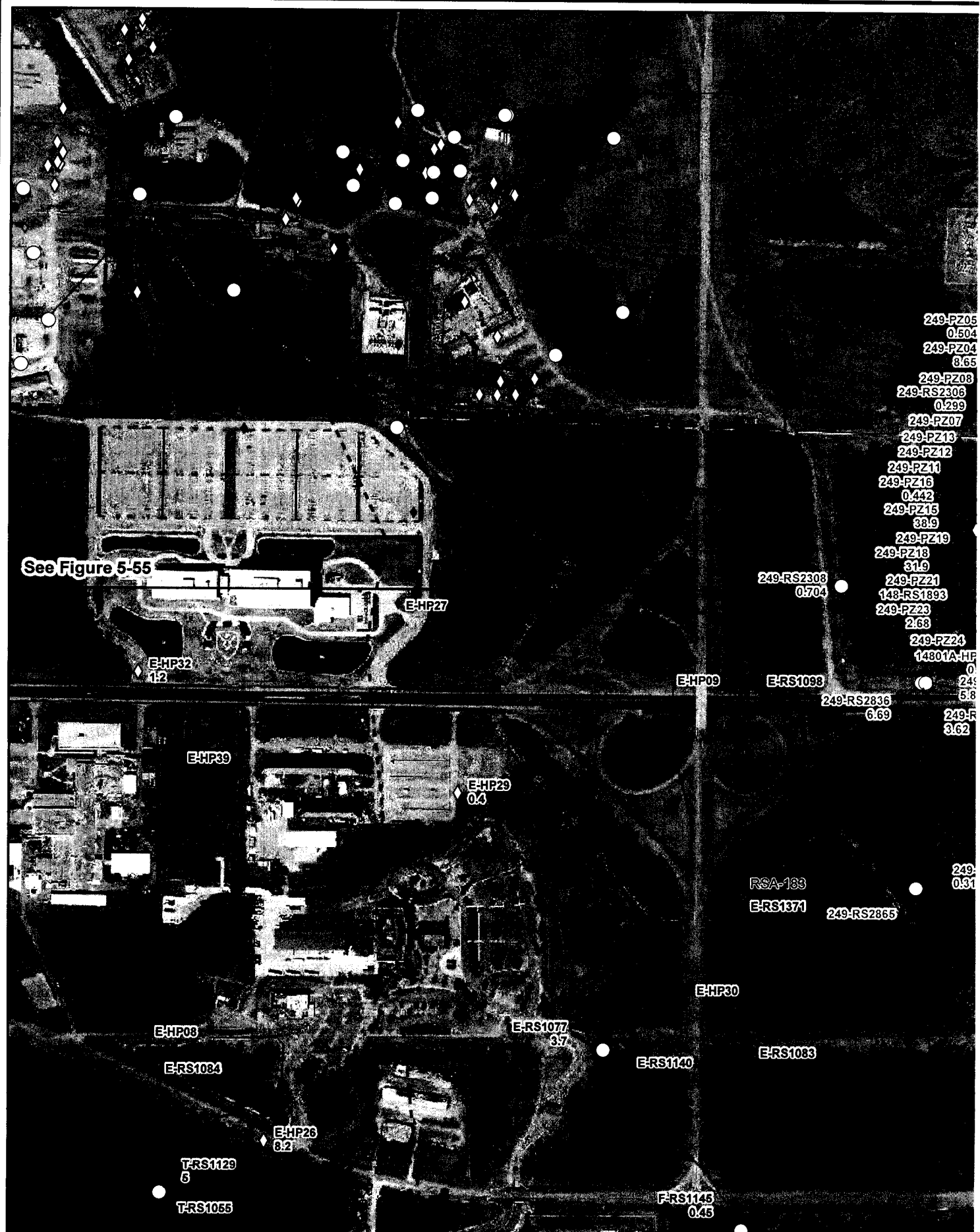




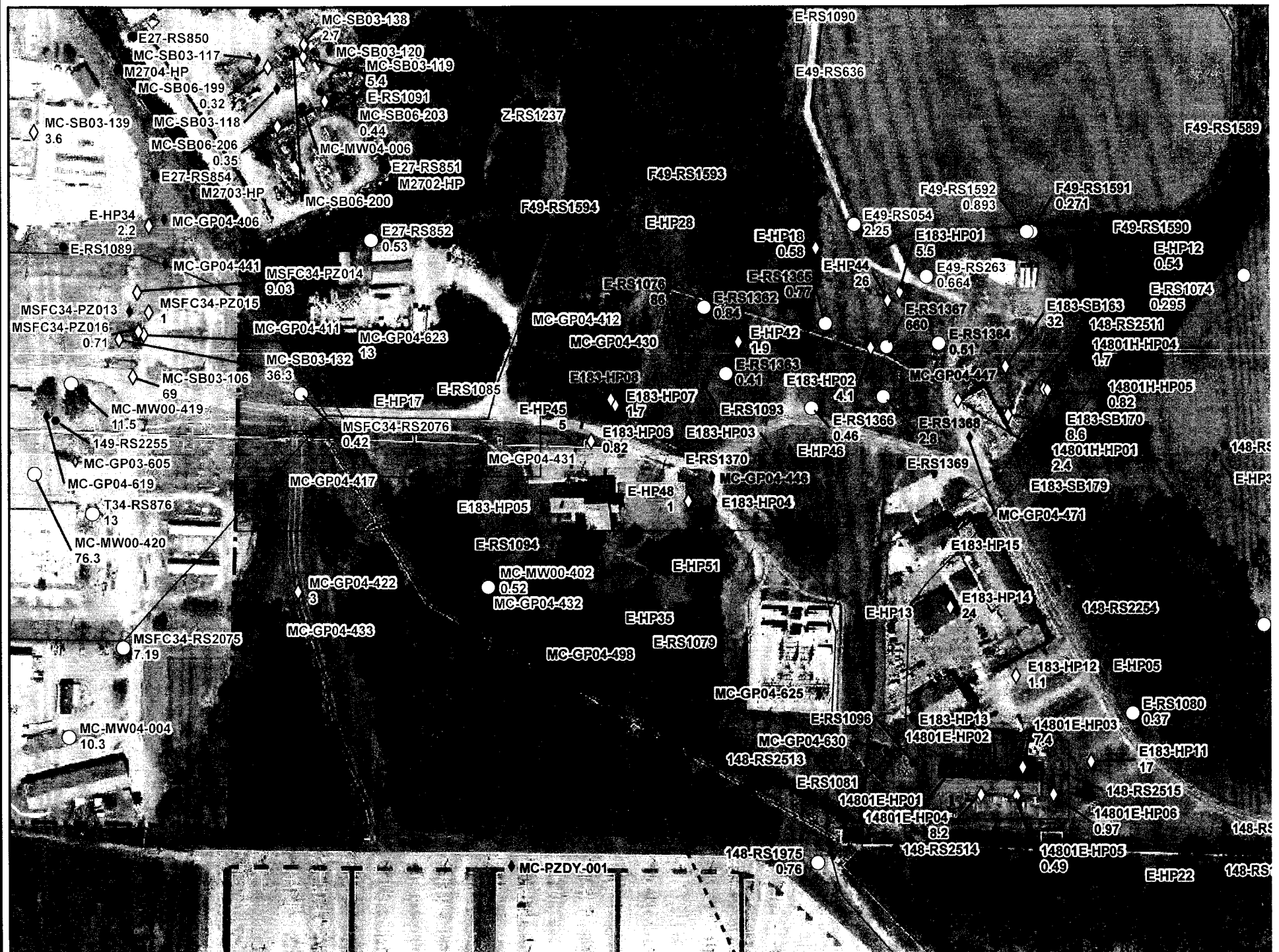




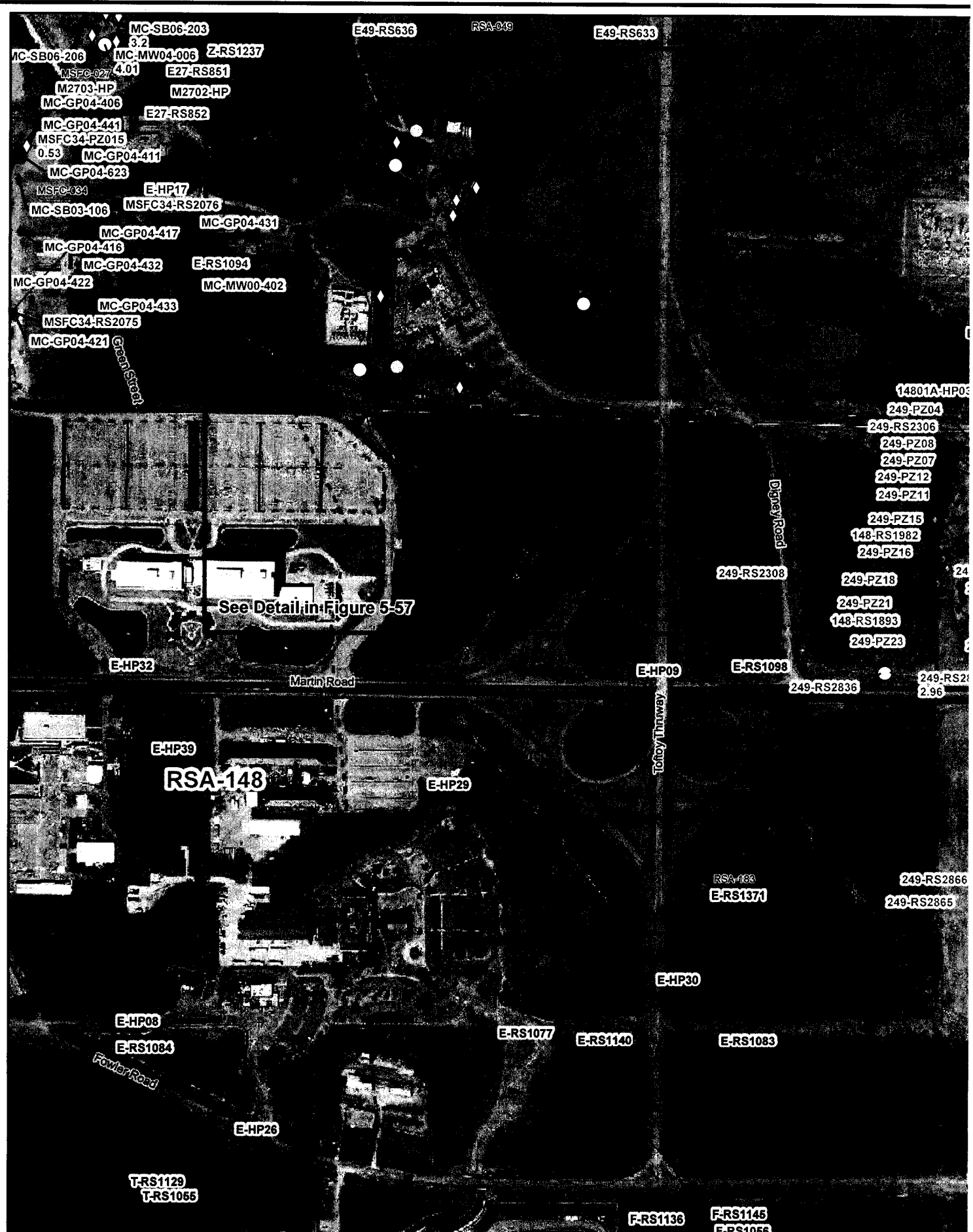


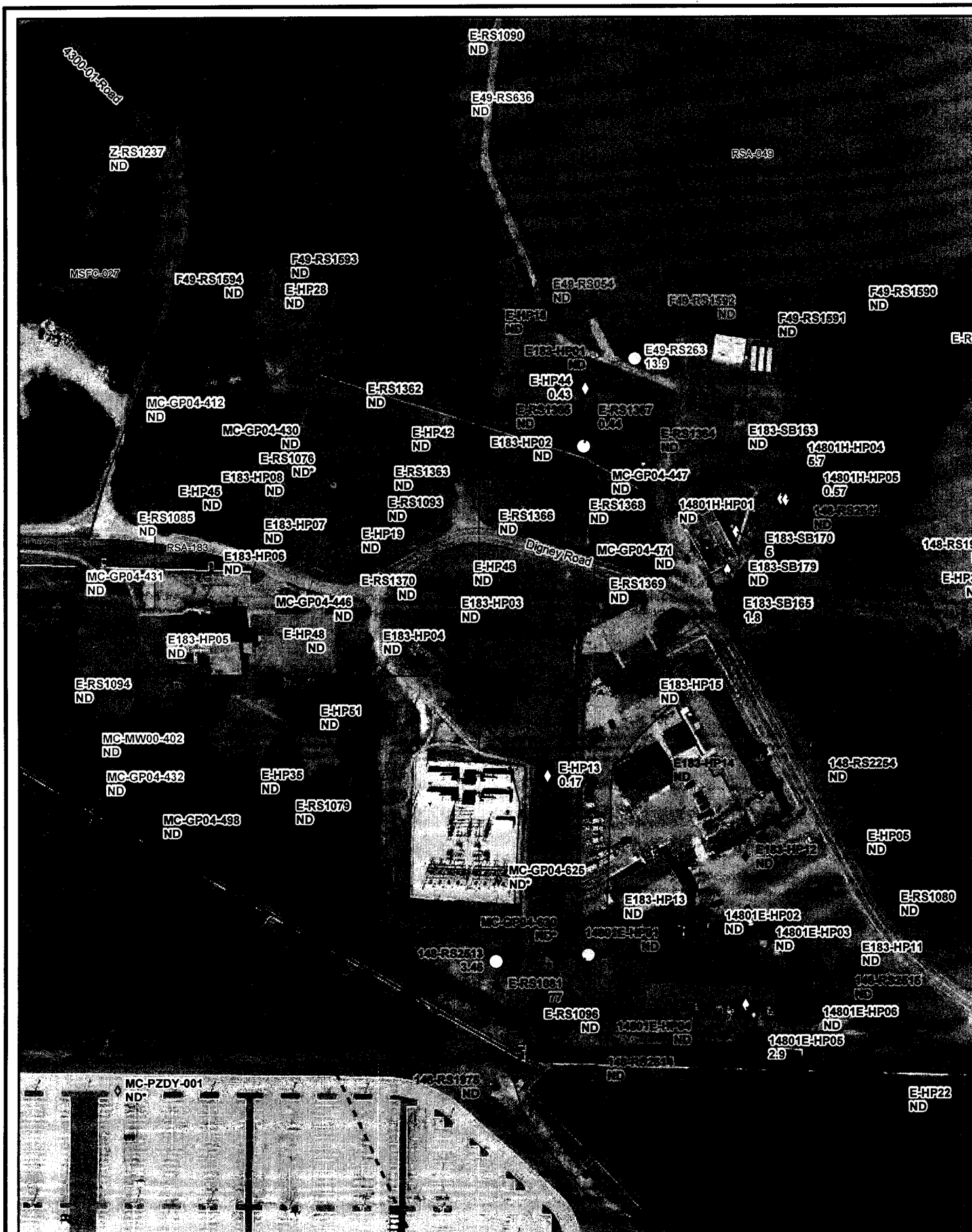


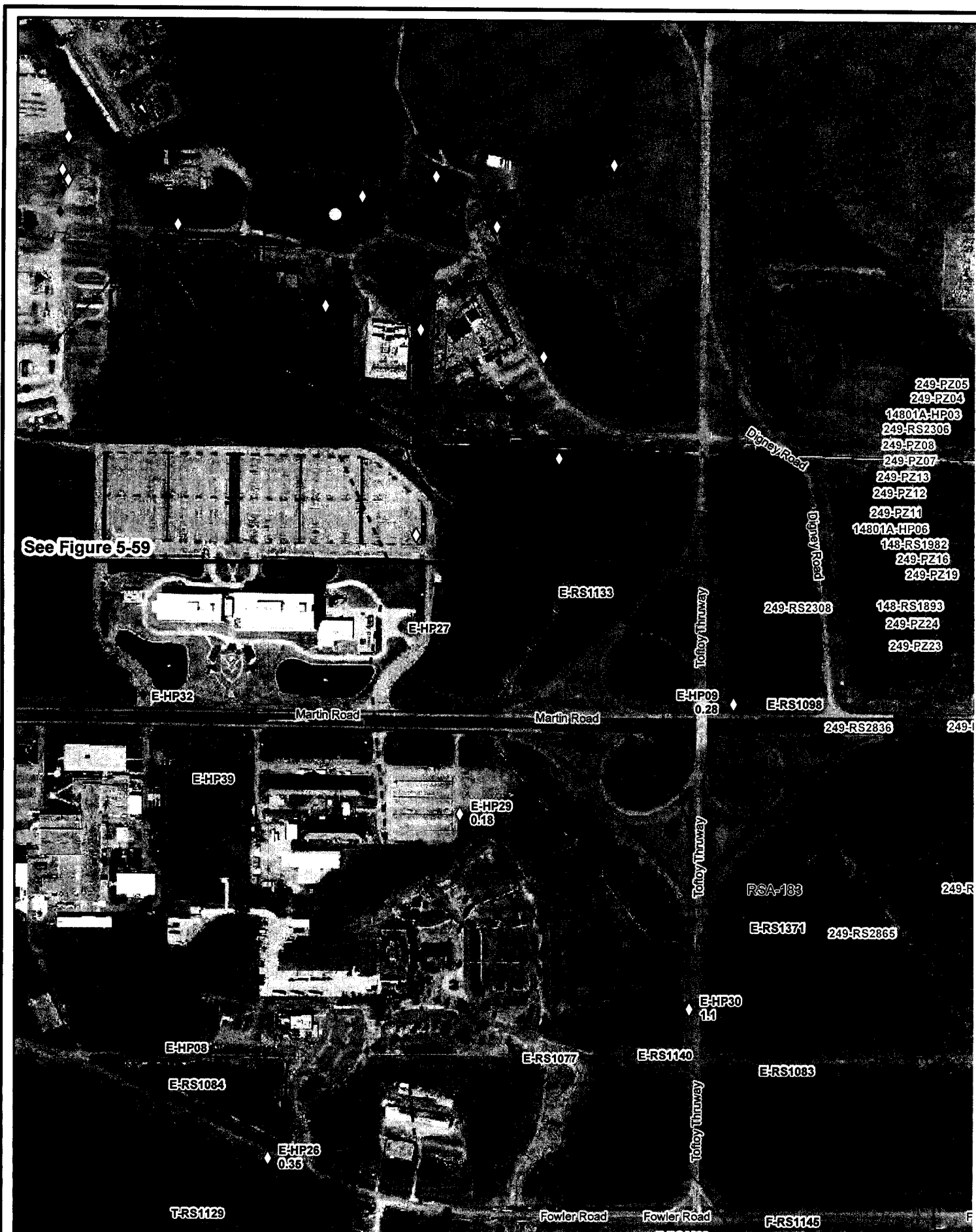


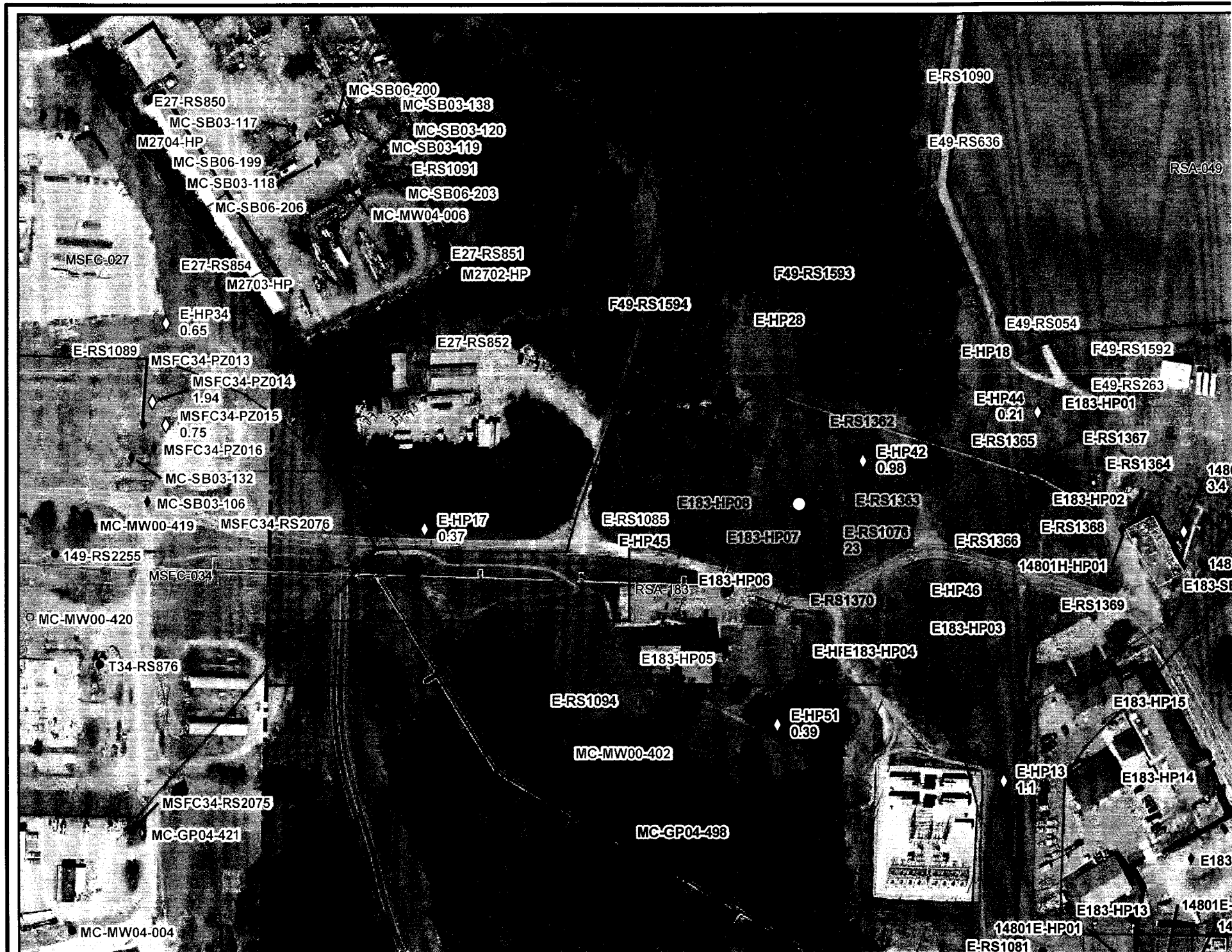














RSA-149

MSFC-027

RSA-049

Digney Road

MSFC-034

T34-RS876  
ND

Mercury Road

Green Street

Toboy Thruway

249-RS2308  
ND

249-RS2836  
ND

Martin Road

RSA-148

E-RS1371  
0.41

RSA-183

E-RS1140  
0.235

E-RS1083  
ND

Fowler Road

T141-RS1146  
ND

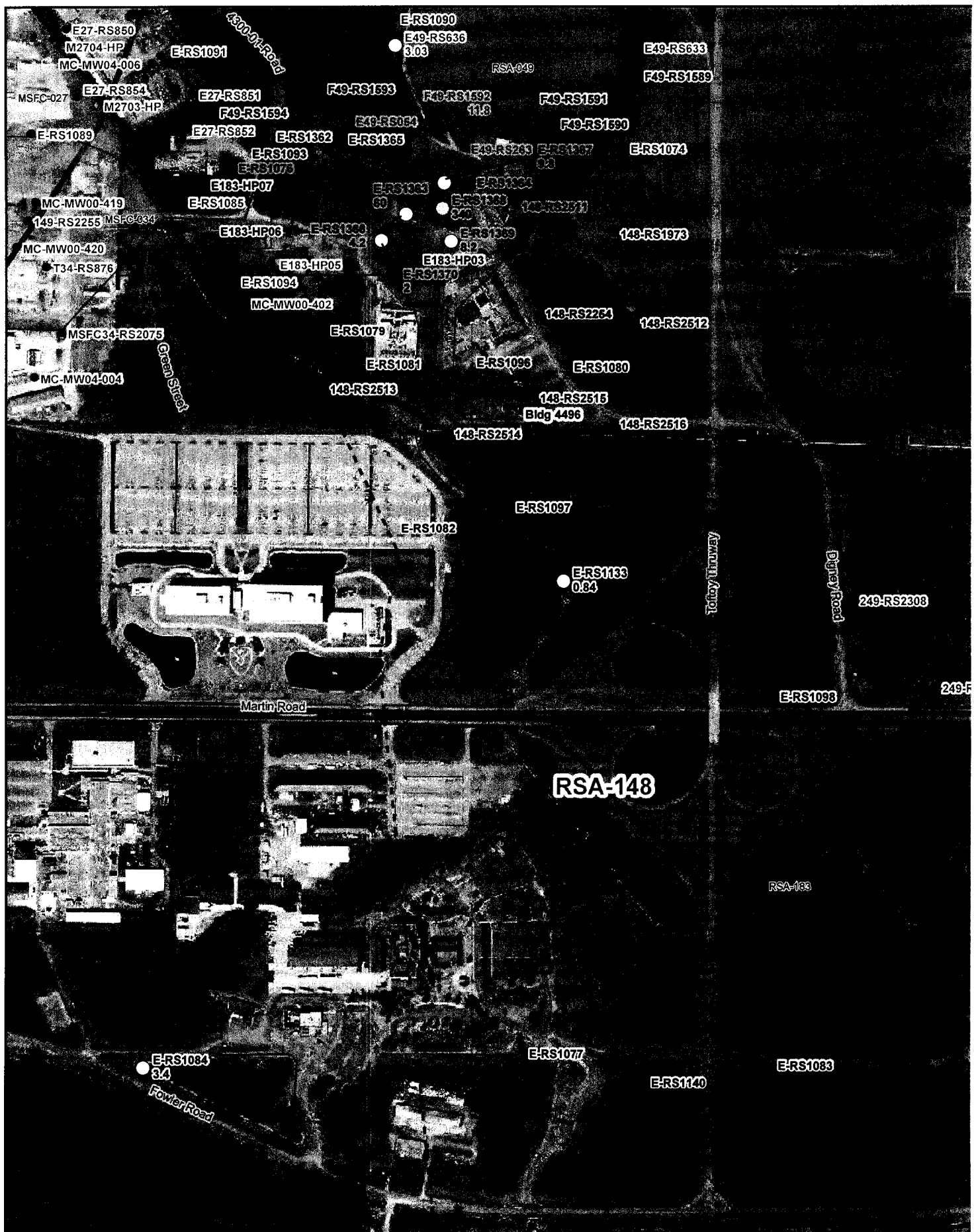
RSA-141

MC-MW00-505  
ND

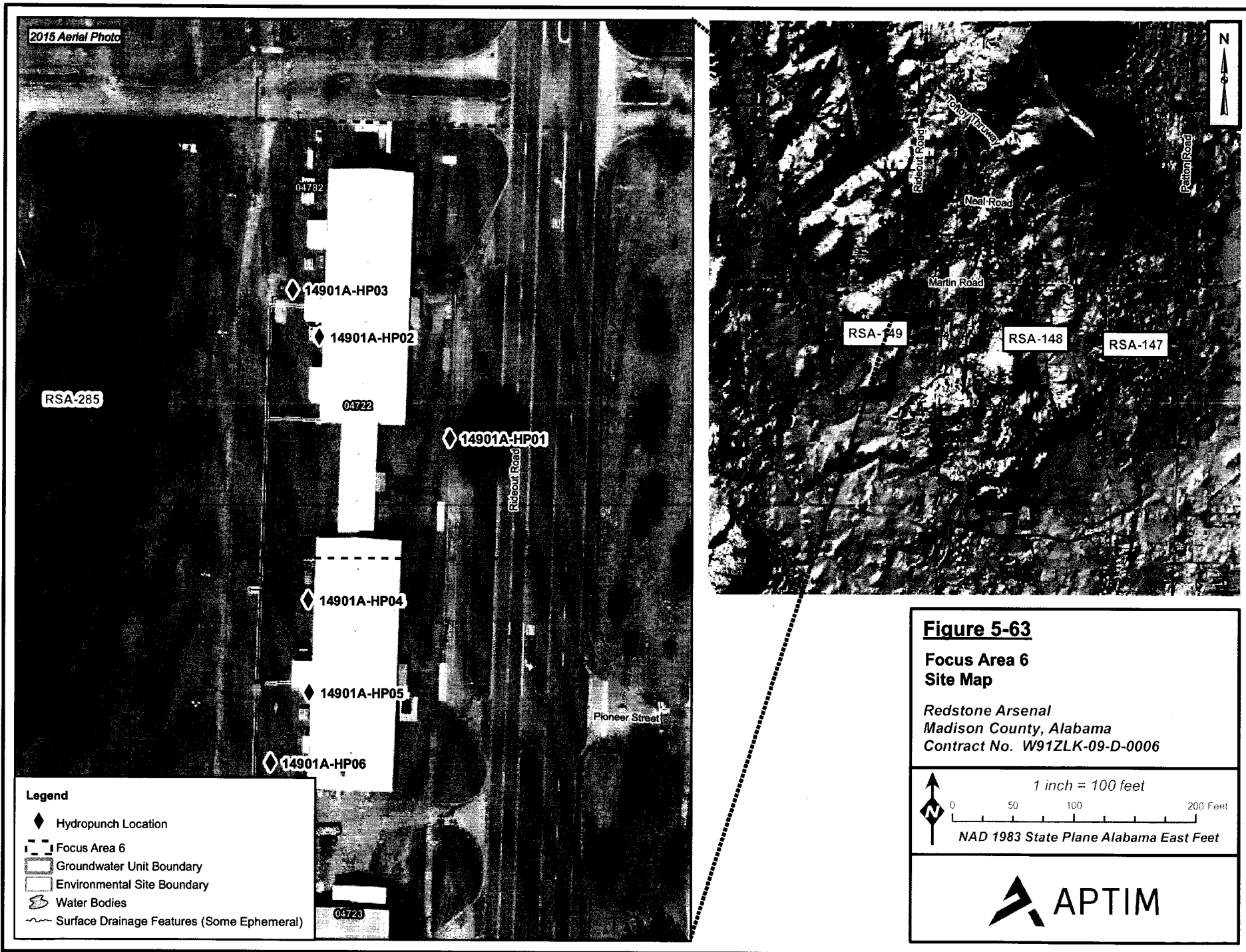
MC-MW04-002  
ND

Dodd Road



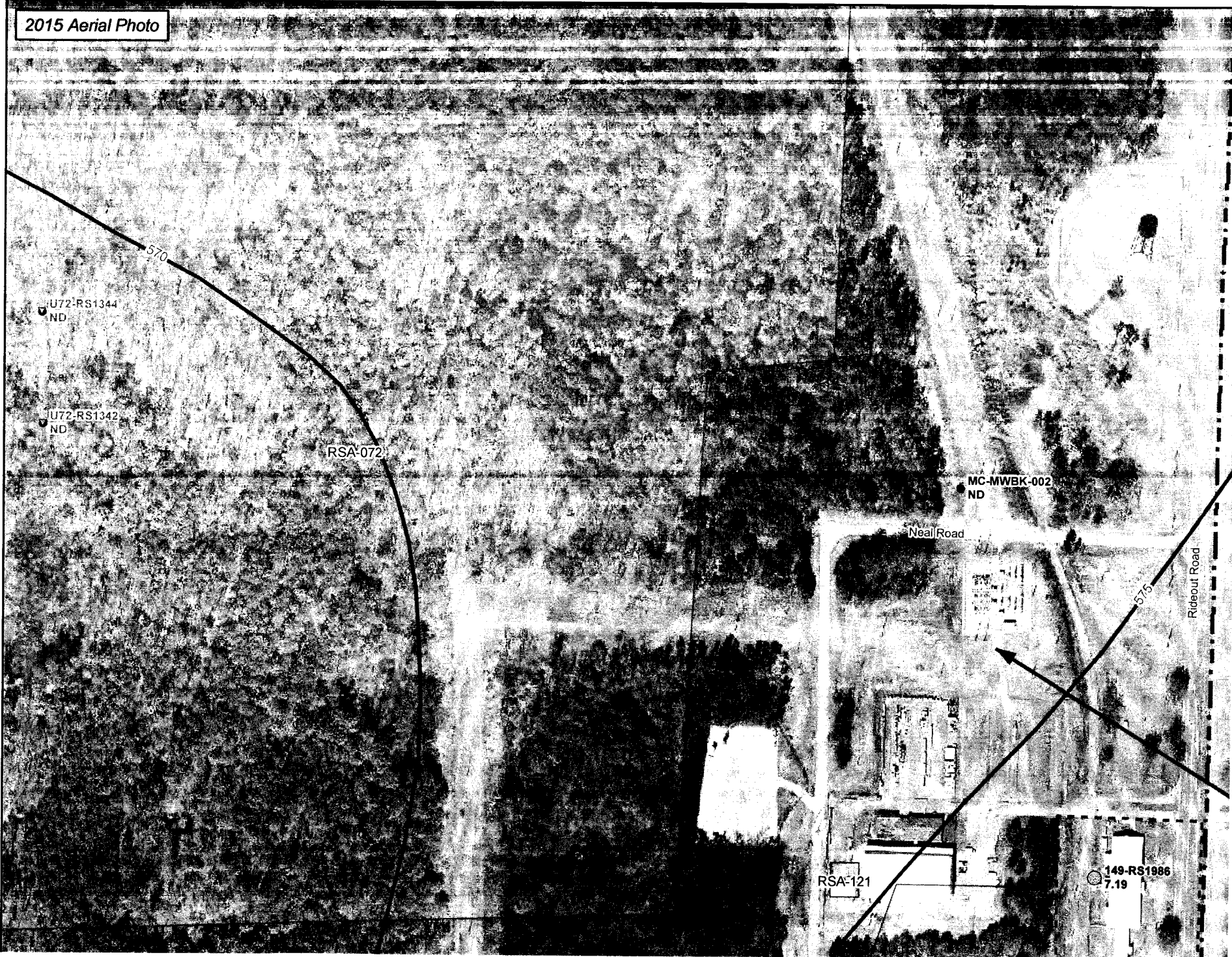


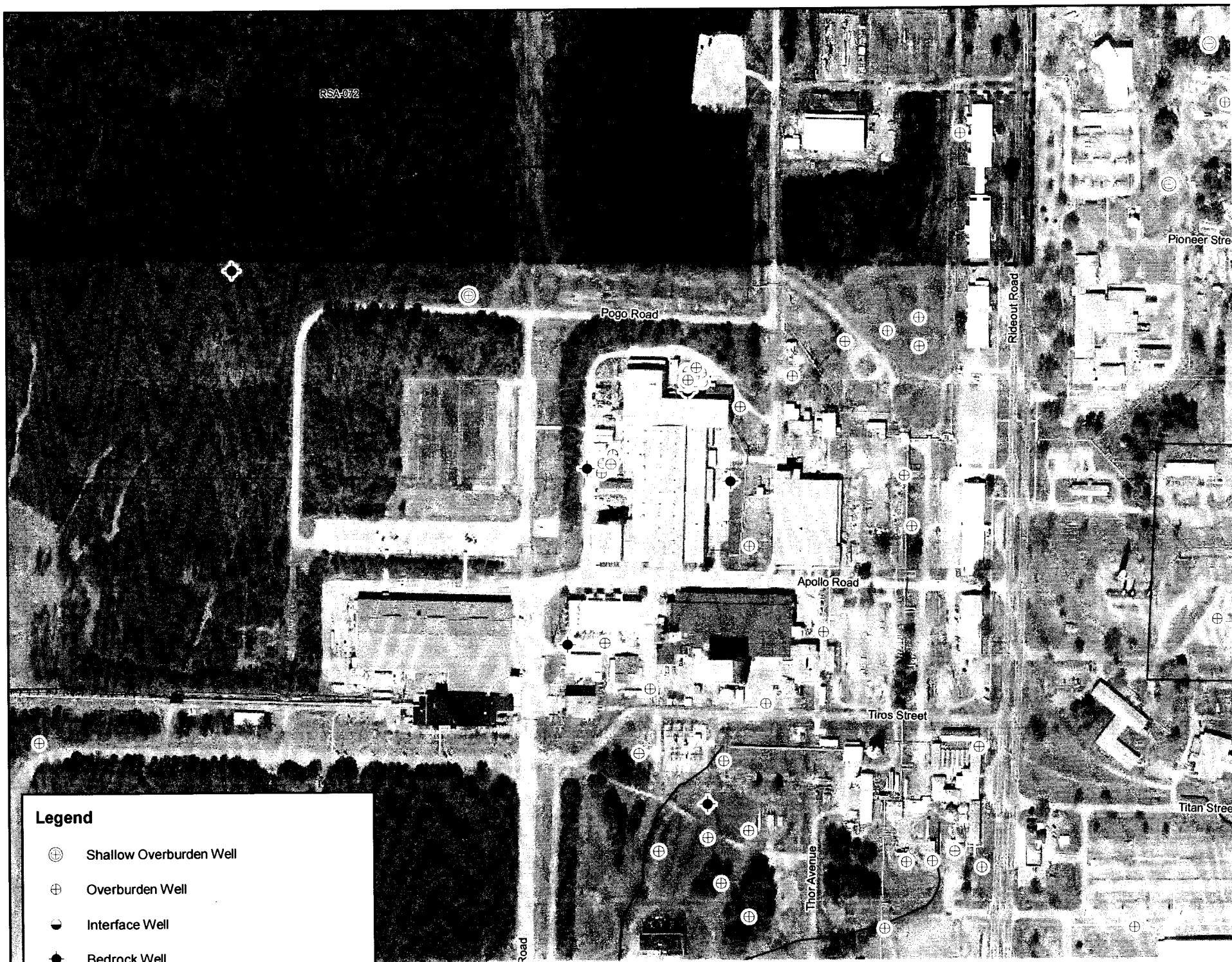


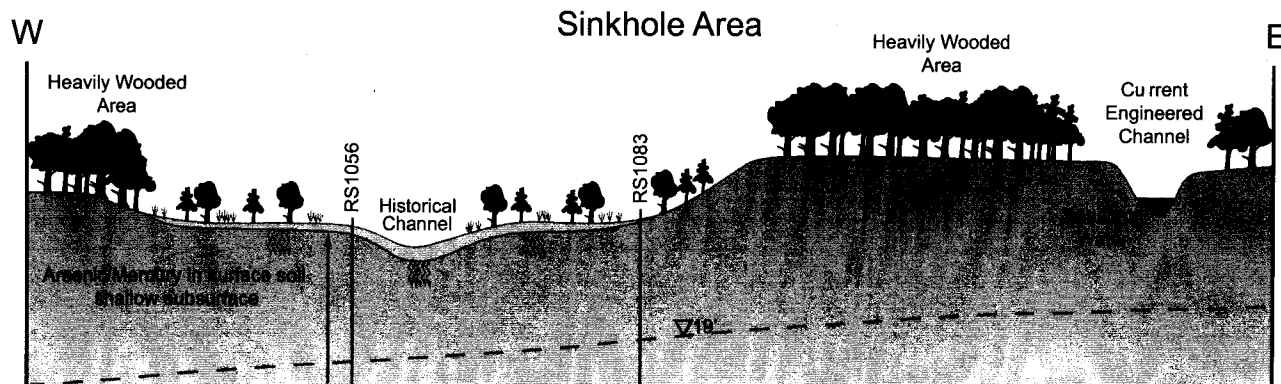
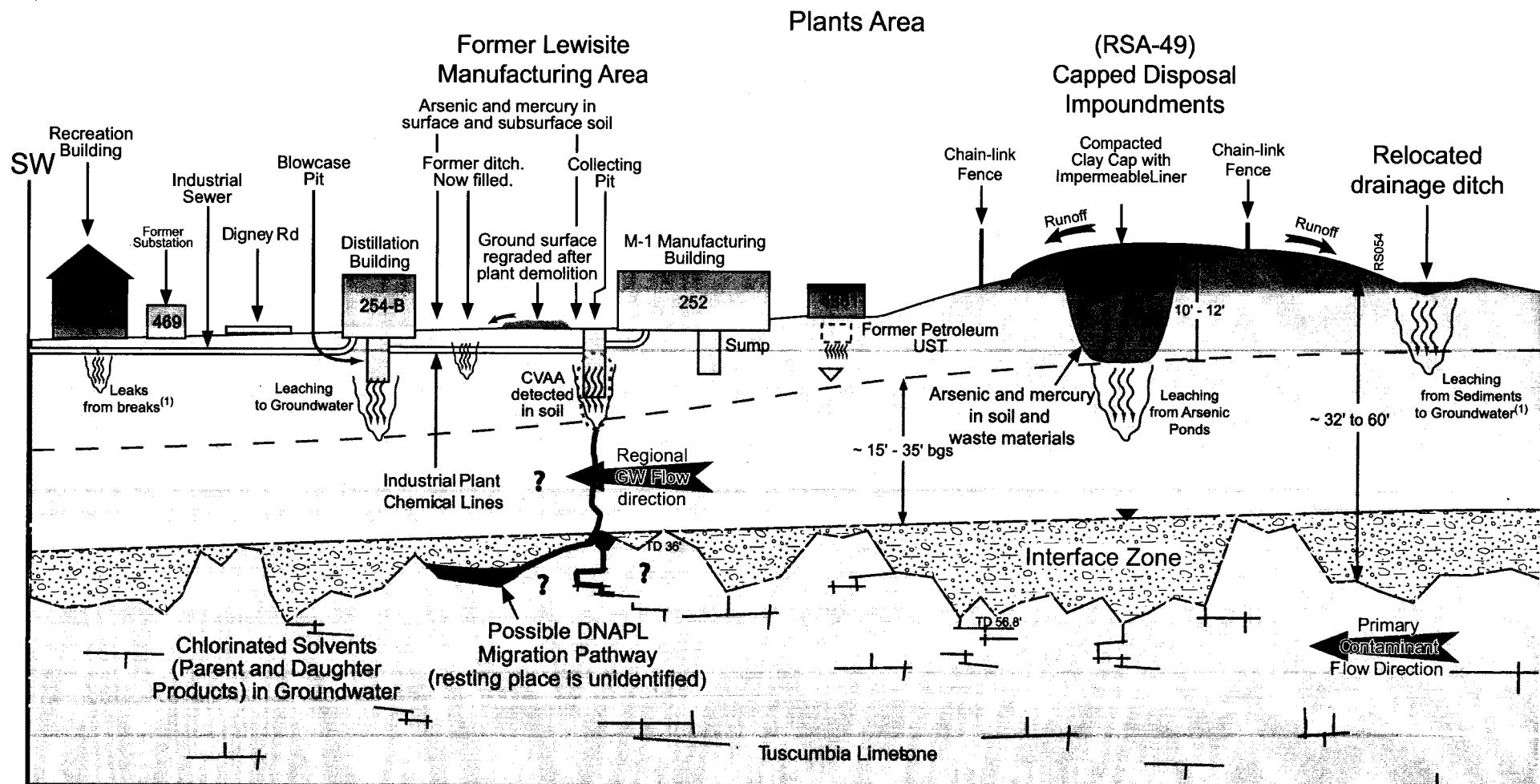




2015 Aerial Photo







## **APPENDICES A – K**

**PROVIDED AS A SEPARATE PDF FILE ON THE ENCLOSED DISC**

## **RESPONSE TO COMMENTS**



**Responses to Alabama Department of Environmental Management Review Comments  
on Rev 0 RCRA Facility Investigation Report RSA-147, RSA-148, and RSA-149,  
Groundwater Sites, Groundwater Units GW-03, GW-04, and GW-05  
Operable Unit 19  
Redstone Arsenal, Alabama  
Dated September 14, 2015**

*Comments by Philip Stroud, Facilities Engineering Section, dated April 14, 2016.*

**General Comments**

**Comment 1:** The Department understands that the objective of this report is to present the nature and extent of groundwater contamination for the RSA-147/148/149 groundwater units. This report presented the results of a multiple phase investigation on a regional groundwater unit scale. However, because corrective measures will be necessary throughout the groundwater units, a more detailed “exposure unit scale” presentation of the results from multi-phase investigation is needed. This in-depth presentation will be needed to ensure that proper corrective measures will be selected to appropriately mitigate any risk the groundwater contamination might pose to end users in individual exposure units. In order to accurately determine this, the nature and extent of each of the plumes/source areas needs to be appropriately investigated. As presented in this report, it appears additional information is needed to determine, in the required detail, the nature of contamination in the sixteen plumes presented in this report. At a minimum this report should outline these information gaps, and provide the appropriate source to obtain this information. Moreover, the Army should seek additional information to fill these data gaps either via additional investigations carried out by each individual surface media site, or RSA-147/148/149 investigations.

**Response 1:** While the Rev 0 document focused on the nature and extent of contamination at the groundwater unit scale, as illustrated in this comment, ADEM is focused on delineation of the specific plume areas within the interior of the unit. Of the 21 Further, based on the comments, additional well installation and sampling of new and select existing wells is warranted. Since issuance of the Rev 0 document and in response to comments, the Army has installed 5 new wells, sampled 58 new and existing wells, and conducted a synoptic water level sweep in order to develop a definitive potentiometric map. Other wells have also been installed since issuance of the Rev 0 document as part of surface media site investigations. These data have all been integrated into the Rev 1 RFI report. Of the 16 plume areas identified in the Rev 0 RFI, only 7 (P01, P02, P04 North, P05, P07, P14, and P15) are the responsibility of the groundwater units RSA-147, -148, or -149. In accordance with the consensus reached at the Comment Resolution Meeting held on 8/23/16, the RFI will only focus on the groundwater contamination and plume areas for which the groundwater units have responsibility. Chapter 1 has been revised to specifically identify the responsibility matrix to set the stage for the document.

The entire Nature and Extent (Chapter 5) has been revamped to provide more detail in the plume areas for which the groundwater units (147, 148, 149) have responsibility for groundwater.

**Comment 2.**

**It appears that the Army has based their understanding of nature and extent on several assumptions as related to depth of contamination. These assumptions include, but are not limited to: tightness or confined nature of the formation at depth which restricts flow, depth of active circulation, parameters that indicate groundwater that is geochemically mature, anoxic reducing conditions with the presence of sulfate and sulfide minerals, natural hydrocarbons, presence of natural gas (i.e., methane), and other indicators such as high chlorides and alkalinity based on relative residence time. Because there is the presence of contamination (i.e., TCE, chlorobenzene, etc.) in a few of the deepest wells drilled in RSA-147, RSA-148, and RSA-149 (RSA-147/148/149), the assumptions noted above do not conclude that the depth of contamination has been determined. The Army has indicated that various springs, wells, and surface water bodies (i.e., streams, creeks, ponded areas, and lakes) have determined the down gradient and lateral boundaries/conditions for contaminant flow.**

**The Department understands the culmination of dye trace studies, geophysical and geochemical studies/investigations, and geological interpretations have indicated the geology and geohydrology of RSA-147/148/149 are complex. These studies and investigations have led the Army to install "Smart Wells" in strategic locations as a result which appear to be beneficial and provide useful data. However, the RFI Report does not present the depth of contamination with defensible evidence in certain areas or areas where there is no coverage with deep wells in the direction of contaminant flow.**

**Because the Army has definitive data/results presenting evidence of contamination at depth in some of the deepest wells drilled, and geophysical and geochemical interpretations based on geophysical studies and sampling, additional information should be provided in areas of known deep contamination to determine the depth of contamination. Once the wells have been installed, sampled, and analyzed, the RFI Report should be revised accordingly.**

**Response 2:**

With a revised focus on areas for which the groundwater unit is responsible, the nature and extent evaluation (Chapter 5) has been completely revamped to specifically present additional defense of the delineation of vertical extent. The Army maintains that the extent of contamination with respect to depth has been delineated. ADEM has consistently requested integration of all available hydrogeologic and other information in the evaluation of nature and extent of contamination. This information was provided in the Rev 0 document and provides further weight of evidence, and has been provided in the Rev 1 document as well. In the complex fractured/karstic bedrock aquifer at this site, flow and contaminant transport occurs within discrete features typically



separated by intervals of impermeable rock. Until intersected by a borehole or a fault, these zones are generally isolated from one another. As a result, a vertical profile of contamination as might be seen in a thick unconsolidated sedimentary aquifer is simply not the appropriate model to consider. Consequently installation of deeper wells in order to establish a non-detect at greater depth in the bedrock wherever shallow contamination is observed is a simplistic and inappropriate approach in this setting.

**Comment 3:** The plume definitions presented throughout the figures in Section 5 are arbitrary and could be interpreted in numerous different ways. Some of the plume boundaries are defined based on well and spring locations at great distances [i.e., in some cases over a mile from the source to a point below preliminary screening values (PSVs)]. Because the Army has based the nature and extent of contamination on a groundwater unit scale, the plume boundaries should be expanded closer to the wells/springs defining them. This would allow for a more conservative approach to defining the contaminant plumes. Please revise Figures 5-6 through 5-48 by expanding the plume boundaries to the extent of the wells indicating non-detects or below PSVs.

There are some cases in which contaminant plumes are defined by wells and springs located at excessive distance as noted above.

**Response 3:** The plume boundaries as shown are not arbitrary as suggested, but drawn to encircle PSV exceedances attributable to a source or group of sources. The boundary of the plume polygons represents a reasonable approximation of the overall extent, all of which are contained within the groundwater unit. The intent was not to extrapolate out to the next nearest non-detect or < PSV location and doing so adds no improved refinement of the nature and extent. In fact, such an approach would overestimate the extent of contamination. In most cases, and particularly in the saturated overburden, the plumes do attenuate within short distances of the source. In such cases extrapolation out to a distal point is inappropriate, particularly in upgradient or side-gradient vectors. Flowpaths can be much longer in the bedrock, as indicated by the dye tracing. In the Rev 1 report an attempt has been made to present the most realistic interpretation of the extent of contamination associated with the plume areas for which the groundwater unit has responsibility. Towards that end the suites of contaminants related to specific sources were used in conjunction with an updated/improved potentiometric map to help constrain the extent of contamination.

**Comment 4:** The rationale used in the construction of the polygons presented throughout the figures in Section 5 appear flawed. For example, in one figure the green points represent 5-100 µg/L. It would be possible that contaminated (>PSVs) groundwater extends beyond the plume boundaries as indicated throughout this report. Generally, the plume must extend laterally to a point which was measured to be below PSV. Multiple programs exist which can mathematically infer iso-concentration contour lines. If the Army has determined these methods

**introduce unacceptable error in plume delineation, then additional field work should be done in order to reduce the error behind these iso-concentration contour lines. These computer derived plumes, which take into account multiple parameters (geology, hydrology, chemical characteristics, etc.) will provide much needed information to the plume delineation as well as assist in planning any necessary corrective measures.**

**The specific comments below indicate that some of the plumes defined by the Army will need to be further assessed to better define the nature and extent of contamination.**

**Response 4:** Inspection of the Chapter 5 COC extent figures indicates there was an error in the scaling of the graduated symbols; each was intended to have concentration gradations in log scale relevant to the range of concentrations observed and the PSV. However, as noted in the comment the final maps were published with uniform gradational scales, where the initial gradation was in all cases 5-100 ug/L. For contaminants present at low concentrations (or with low PSVs), those scales do in fact make it difficult to determine the magnitude of the concentrations in wells along the boundary of the defined plume areas such that it is less clear whether the concentration is near the PSV or much higher. This has been corrected in the Rev 1 document.

The computer derived plume mapping that addresses all the multiple parameters discussed in the comment amounts to flow and transport modeling (this is NOT addressed by typical contouring programs). Such modeling is not appropriate to the highly anisotropic and heterogeneous aquifer media at Redstone. In many cases, additional wells are not needed, especially if simply intended to refine the extent of contamination. Observations of the rate of lateral attenuation (in a down or side-gradient vector) where delineation control is adequate can and should be used as a basis for extrapolation of the extent of contamination. Where well control is dense enough to document attenuation within a specified distance for among one side of a plume, there is no reason to expect similar conditions would not prevail on the other side. Such information is appropriate for use and has been applied in interpretation of plume extent.

**Comment 5:** Figure 3-8 shows the RSA-147/148/149 potentiometric surface map from September/October 2014 water level measurements. After review of the RSA-147/148/149 RFI Report, this potentiometric surface map appears very general and does not show the details of smaller scale flow patterns as described in individual RFI Reports. This larger scale can lead the reader to assume that wells at great distances from the source are downgradient wells, side gradient wells, or upgradient wells when in reality they are not. For example; Figures 1-3 and 1-4 from the Revision 2 Corrective Measures Implementation (CMI) Plan for RSA-054/055 indicate a northerly groundwater flow in wells F54-RS297, RS298, and RS304; however, Figure 3-8 in the RSA-147/148/149 RFI Report indicates groundwater flow to the west. Well F54-RS304, for example, has an

arsenic concentration of 30 µg/L and appears to be flowing to the west in Figure 3-8. It is unclear if this should be of concern to the RSA-054/055 RI Report to complete the nature and extent. The Army should consider re-evaluating the RSA-054/055 RI Report for nature and extent and contaminants of concern. According to this RSA-147/148/149 RFI Report, the nature and extent has been determined but the report does not indicate which wells to the west define the nature and extent. This RSA-147/148/149 RFI Report does not appear to use the details of individual RFI Reports along with Figure 3-8 to determine nature and extent. The Department's review of the RSA-147/148/149 RFI Report included review of individual RFI Reports to make determinations on nature and extent of groundwater and are incorporated in the Specific Comments below. The next revision of the RSA-147/148/149 RFI Report should include more detailed analyses of groundwater flow patterns to determine nature and extent.

- Response 5:** Potentiometric mapping presented in the surface media site RFI reports are focused on that site scale and in most cases were not generated within the context of the larger potentiometric surface. While there may appear to be flow in an opposing direction when comparing the two map scales, the site scale mapping is only a localized phenomenon. This is compounded by the fact that the majority of the surface media sites are situated within the most developed portions of the groundwater unit, where there is considerable anthropogenic factors that impart anomalous water levels. Such factors include :
- Paved areas. Paved areas limit recharge and may result in lower heads in wells installed within the paved area. Conversely, recharge may be focused along the downslope edges of the pavement, if not captured by storm drains.
  - Capped areas. As a result of the remedies conducted thus far, impermeable or low permeability caps have been installed at a number of sites (RSA-049, RSA-060, RSA-056/139). Similar effects on recharge occur as with paved areas.
  - Water supply lines (potable and fire water). These lines are nearly 80 years old and under pressure, can and do leak, often at junctions, valves and hydrants to create localized mounding. The leaks are ongoing and typically sustain elevated water levels in wells that otherwise would experience much more seasonal variability. Nonetheless, these mounding areas can influence groundwater flow and contaminant transport if only on a local basis.
  - Steam lines. The overhead steam line network includes blowdown valves and sumps at periodic intervals along the lines. These blowdown features can also result in localized recharge resulting in mounding of a limited areal extent. One known example occurs within RSA-122 where the area within 30 ft of the blowdown sump is completely saturated.

- Stormwater drains and retention ponds. The subsurface stormwater network is also nearly 80 years old and, where leaking represents another source of anthropogenic recharge. Although such leaks are more commonly observed at junctions, the lines themselves may also leak – the integrity of the stormwater drainage lines is not known. Similarly, there are stormwater retention ponds. Although most are lined (either with synthetic liners or clay), these features may also serve as localized recharge sources resulting in mounding.
- Building roof drains. Within the developed areas of the unit there are a number of buildings, many of which cover a considerable surface area. Recharge to groundwater may be reduced under the footprint of such buildings. Rainfall runoff from the buildings may be captured by storm drains (see above), but also may result in focused points of recharge at downspouts.

The impact of the above factors is evident in what appears to be anomalous elevated or depressed water levels. Further, saturated intervals have been encountered in association with weathered/permeable zones within the overburden at depths well above the ambient water table at many of the sites. Wells installed in those intervals yield heads that are much higher than the surrounding water table. When used at face value in contouring the shallow saturated heads result in anomalous gradients relative to the true water table. Where the elevated heads are sustained by anthropogenic recharge throughout the year, this can result in apparent gradient reversals as the heads in the other wells fluctuate seasonally.

To address ADEM uncertainty regarding relevant hydraulic gradients to be used in determining nature and extent a number of things have been done. First of all, another comprehensive water level sweep was performed in February 2017 focusing solely on the areas of groundwater unit responsibility. The September 2014 mapping provided in the Rev 0 report will now be supplemented by the February 2017 potentiometric map, which together reflect the dry and wet season extremes, respectively. In selecting wells for water level measurement in the 2017 event a focus was placed on those wells that truly represent the water table, and then within the area of groundwater unit responsibility. Shallow perched water wells were excluded. Deeper bedrock wells were only measured if paired with a shallow well. Similarly, only wells representative of the water table were utilized in contouring the 2014 and 2017 potentiometric maps. In order to address ADEM concerns, the plumes and potentiometric surfaces published in the surface media site RFI reports were consulted and considered. Finally, supplemental 1-ft contours have been added to the 5-ft contour interval in the 2017 mapping.

**Comment 6:** The figures in Section 5 (i.e., Figure 5-6a through 5-48b) and figures in Appendix E (i.e., Figures E-1a through E-23b) should, at a minimum, show the well designations for the contaminated wells above PSVs along with the wells that define the plume boundaries. The cross-sections only show wells in a linear fashion and do not present all wells that fully define

**the plume boundaries. Labeling the wells above PSVs and the wells that define the plumes (i.e., wells below PSVs) would allow the reader to quickly reference other figures and associated tables.**

**In addition, labeling wells in Figure 3-8 and showing the boundaries of the surface media sites would allow the reader to quickly reference other figures and associated tables. Please revise the figures in Section 5, Appendix E, and Figure 3-8 as noted above.**

**Response 6:** The density of wells and number of plumes within these three groundwater units pose a significant challenge in presenting and conveying the analytical results. Even lacking labels the maps are “full”. It is further recognized that flipping back and forth between the COC distribution maps and other maps, such as the labeled wells figure or the potentiometric map can be tedious to a reviewer. In the Rev 1 document, the nature and extent presentation has been completely revamped. With a revised focus on only those plume areas that are the responsibility of the groundwater units, this allowed portrayal of data on a series of larger scale (improved resolution) maps pertinent to each of the [revised] plume areas. Focusing on the areas of groundwater responsibility also reduced the number of COCs to address; some were only present at sites/areas which hold the responsibility for groundwater. Overall the graphics in the Rev 1 document were improved to the degree possible to allow ADEM to more readily evaluate the adequacy of the delineation. For example at the scale of the new mapping it is possible to label many if not all of the wells. Similarly the 2017 potentiometric surface was added as a base layer.

The cross sections were developed to display nature and extent at the unit scale and were never intended to delineate the interior plumes. As such they focused on inclusion of as many deep wells and paired/clustered/multizone wells as possible. Based on ADEM focus on the interior plume delineation and the revised focus on those that are the responsibility of the groundwater unit, those sections are no longer included in the Rev 1 document. They have been replaced with cross sections and other relevant graphics on the plume “exposure unit” scale preferred by ADEM.

**Comment 7:** Sites that are pending RFI submittals include MSFC-034, 035, RSA-052, 010, 109, 117, 216, 238, 249, 290, 317, and RSA-F. Some of the RFI Reports for individual sites are being revised and additional investigations are required for some (e.g., RSA-252, RSA-117, etc.). The deferred sites, in some cases, will not be investigated for many years to come (e.g., RSA-052 (August 3, 2021), RSA-061 (February 4, 2021), RSA-062 (February 4, 2021), etc.). It appears that additional investigations should be performed to determine the nature and extent of groundwater contamination. The specific comments below and the general comments above address the need for more investigations to delineate the groundwater plume boundaries both vertically and laterally.

**Response 7:** Disagree. Of the sites listed in the comment, only RSA-109, RSA-216, and RSA-290 are the responsibility of the groundwater units. The Rev 1 RFI for

RSA-290 is scheduled for submission to ADEM in April 2017 and the Rev 0 RFI for RSA-109 is slated for submission in May 2017. The delineation of groundwater at both sites is complete.

At RSA-F, the RFI has been completed (report submitted Sept 2016) and the conclusions were that no COCs were present in groundwater (i.e., NFA for soils and groundwater. The surface media sites are responsible for groundwater in the remaining sites.

**Comment 8:** Because the nature and extent of contamination has not been fully determined based on the general comments noted above and the specific comments noted below, Chapter 6.0 (Contaminant Fate and Transport) and Chapter 7.0 (ARBCA Human Health Evaluation and Screening-Level Ecological Risk Assessment Summary) will need to be updated and addressed in the next revision of the RSA-147/148/149 RFI Report.

**Response 8:** Comment noted.

**Comment 9:** It is the Department's view, that while the Army is completing the nature and extent of contamination for RSA-147/148/149, measures can be taken to start remediation of the groundwater plume areas, especially in the areas of highest concentrations. Interim measures are encouraged while the additional investigations are ongoing to determine nature and extent of groundwater contamination.

**Response 9:** Comment noted.

#### **Specific Comments**

**Comment 1:** **Page ES-1 Executive Summary:** The Executive Summary concludes that the nature and extent of groundwater contamination has been determined. The Department does not agree that the nature and extent of contamination has been determined based on the following Specific Comments below and General Comments noted above. Please refer to General Comments noted above and the following Specific Comments below and revise the RFI Report accordingly.

**Response 1:** See responses to comments above and below.

**Comment 2:** **Page ES-1, Executive Summary, Third Paragraph, Last Sentence:** The sentence lists pesticides twice. Please revise the sentence accordingly.

**Response 2:** The text will be revised per the comment.

**Comment 3:** **Page ES-1, Executive Summary, Third Paragraph:** Principle contaminants (COC) present in RSA-147, RSA-148, and RSA-149 are listed. Chiefly, 1,1,2,2-tetrachloroethene is one of three main volatile organic compounds (VOCs). Clarify if this is tetrachloroethene (PCE) or 1,1,2,2-tetrachloroethane (acetylene tetrachloride).

**Response 3:** The intended compound was 1,1,2,2-TeCA. The text has been revised accordingly.

**Comment 4:** **Page 1-2, Section 1.3, The Watershed Investigation Approach, Second Paragraph, Second Sentence:** The sentence references Figure 1-2 and Table 1-1. Figure 1-2 and Table 1-1 do not match the sites completely. Figure 1-2 is lacking numerous sites that are indicated in Table 1-1 (i.e., MSFC-002/087, MSFC-003, 035, 043, 053, 055, 060, 065, 074, 077, D and 082, RSA-033, 043, 044, 103, 104, 105, 106, 107, 123, 124, 125, 223, 224, 251, 270, 277, 279, and 285). Please revise Figure 1-2 to show all locations noted in Table 1-1.

In addition, please revise Figure 1-2 by defining the integrator operable unit (IOU) boundaries by different colors. This will make it easier to determine the IOU boundaries. If it is not feasible to use Figure 1-2 for these color designations, please add an additional figure to show the IOU site boundaries within the RSA-147/148/149 groundwater unit.

**Response 4:** Figure 1-2 has been revised to show all of the sites listed on Table 1-1 (and in the comment). The figure has further been revised to more clearly document the boundaries of the IOUs. Table 1-1 has further been revised to remove MSFC-043, which does not lie within the subject groundwater units. Some of the SWMUs are small and contained within other SWMUs such that at the scale of the figure they are difficult to show let alone label.

**Comment 5:** **Page 1-2, Section 1.3, The Watershed Investigation Approach, Second Paragraph, Last Sentence:** RSA-147/148/149 lies in the central portion of RSA and spans portions of the central Indian Creek and eastern McDonald Creek. RSA-147/148/149 does include portions of Indian Creek but none of McDonald Creek is included in these site boundaries. This information is better reflected in other sections (as in Section 1.5). Please clarify if Huntsville Spring Branch comprises the southern portion of RSA-147/148/149 and does not include McDonald Creek.

**Response 5:** The text describes where RSA-147/148/149 lies with respect to the 3 large watersheds at RSA, not surface water bodies. However, the text in the referenced sentence requires clarification that these units lay within the Indian Creek *Watershed* and the McDonald Creek-Huntsville Spring Branch *Watershed*. The text has been revised to reflect this clarification.

**Comment 6:** **Page 1-2, Section 1.3 The Watershed Investigation Approach:** This section describes the broad groundwater units as decided on in 2002. It also outlines the methods in place to determine investigation and remediation responsibility to groundwater or surface media sites. Over the years these methods have been discussed extensively and have evolved from investigation and remediation of comingled plumes and single anomalous groundwater exceedances to investigation and remediation of multiple groundwater plumes which can be directly linked to activities at surface media sites. Furthermore,

there are discrepancies in multiple reports as to who is responsible for the investigation of groundwater contamination underlying surface media sites. To even further complicate this matter, multiple surface media sites are currently being investigated, or have yet been investigated. Therefore, concurrence as to which site should handle the investigation and remediation has not been granted. In light of these multiple complexities, a table should be included in the report. This table should include: every permitted surface media site, whether these sites require(d) a RFI, the status of this investigation, groundwater responsibility determination of the Final RFI (if applicable), and Contaminants of Concern (COCs). At least six (6) sites do not have enough information to determine the groundwater responsibility, therefore the report needs to explicitly discuss how these sites will be managed. Upon finalization of the RSA-147/148/149 RFI, any remaining surface media sites should plan to investigate and remediate all media.

**Response 6:** Table 1-1 has been revised (and updated) to include for every SWMU within the three groundwater units, the most current status with respect to the Permit and RFI completion, along with the final determination of responsibility with respect to groundwater. All surface media sites are responsible for delineation of groundwater and are conducting investigations accordingly. The exception to this are legacy sites accepted by ADEM as NFA and sites investigated (and in cases remediated with respect to surface media) under CERCLA.

**Comment 7:** **Page 1-4, Section 1.5, RSA-147/148/149 Site Description, Last Sentence:** The sentence indicates that a portion of the Wheeler National Wildlife Refuge lies in the southern portion of RSA-147/148/149. Please revise the paragraph by adding a sentence referencing Figure 1-1 showing the boundaries of Wheeler National Refuge.

**Response 7:** The text has been revised to insert a reference to Figure 1-1.

**Comment 8:** **Page 1-8, Section 1.5.3, RSA-149, Bullet at top of page:** The bullet states, "Two chemical warfare material demilitarization and disposal areas (RSA-052 and RSA-109) on the north side of Huntsville Spring Branch." Please revise the bullet by adding RSA-063 and RSA-264 on the south side of Huntsville Spring Branch in Test Area TA-1.

**Response 8:** The text has been revised to address the comment.

**Comment 9:** **Page 2-2, Section 2.1, Sitewide Karst Hydrogeologic Investigation, Second Bullet,** The bullet indicates that nine springs were sampled in July 1999, and three were resampled in March 2000. Acceptable data in this RFI Report were based on 2007 data and later. The Army should resample these springs at a minimum to establish a current baseline and revise the RFI Report accordingly.

**Response 9:** This summary is only to provide the reader with a chronologic overview of the work that has been conducted within these groundwater units, in this case to document the history of spring sampling. This is not to imply that these



springs were not sampled again at a later date. A thorough data usability analysis of all data was conducted, and the results of this sampling event were not used in the evaluation.

**Comment 10:** **Page 2-4, Section 2.3.3, NASA MSFC Dye Trace, Top Paragraph, Second Sentence:** The sentence states, “The scope of the NASA tracing is summarized in Table 2-1, with injection and monitoring locations shown on Figure 2-1.” Figure 2-1 does not show injection and monitoring locations nor does it indicate the locations in the Legend. Please either revise Figure 2-1 to show these injection and monitoring locations or provide an additional figure showing the injection and monitoring locations.

**Response 10:** The text citation to Figure 2-1 is incorrect; there is no such figure. The text has been revised accordingly.

**Comment 11:** **Page 2-10, Section 2.9 RSA-147/148/149 RFI Field Investigations:** Four separate phases ranging from 2011 to 2014 are described in this section. Throughout these four (4) phases, numerous samples have been taken, and multiple different analytical suites have been sampled for. The Department understands that throughout these multiple phases, work plans were drafted and sampling programs were developed based on site conditions, historical processes, previous sample results, etc. However, these sections fail to provide this information. Please revise the report to include at minimum a brief summary behind the rationale of the different analytical suites employed throughout the four phases of the investigation.

**Response 11:** Disagree. It is not the intent of this report to regurgitate the rationale provided in the referenced work plans. All of the wells installed as part of these investigations were intended to supplement the existing monitoring network in the delineation of lateral and vertical extent of contamination. The locations and analytical suites were selected to match the CSM for the SWMUs (where focused) and/or the groundwater unit, all of which was presented or discussed with ADEM beforehand. The purpose of this chapter is to provide an overview of the various investigations that have taken place which yield data applicable (upon screening) for use in describing the nature and extent of groundwater contamination. The rationale for each sample collected in the past does not contribute to that objective. However, the text has been modified somewhat to reflect the overall objectives of the tasks completed.

**Comment 12:** **Page 2-12, Section 2.9.3, RSA-147/148/149 Supplemental Phase 2 RCRA Facility Investigation, Top Bullet, Second Sentence:** The sentence states, “The remaining locations were not sampled since the wells were no longer present.” Please revise this bullet by providing which wells were no longer present for sampling and discuss how the wells were abandoned or removed. Please also determine if the missing wells should be re-drilled and sampled based on strategic locations.

**Response 12:** Which wells were not available for sampling and the nature of the closure is irrelevant to the discussion, which focuses on the fact that wells and springs

were sampled as part of the Phase II RFI, the results of which contribute to the overall data available for inclusion (based upon screening) in this RFI. The text has been revised to delete the extraneous statements not pertinent to this objective.

**Comment 13:** **Page 2-13, Section 2.9.4, RSA-147/148/149 Supplemental Phase 2b RCRA Facility Investigation, RSA-147, Fourth Bullet, Second Sentence:** The sentence states, “The nine newly installed wells in RSA-054 and 147-RS22471 were sampled for VOCs, pesticides, PCBs, TAL metals, total dissolved solids (TDS), total organic carbon (TOC), chloride, nitrate, sulfate, dissolved gases, alkalinity, dissolved iron (ferrous/ferric), and DHC.” Please revise this bullet by clarifying why TCL SVOCs, PAHs and low level PAHs were not sampled in the nine newly installed wells noted above.

**Response 13:** In each case the analytes selected for sampling was dependent on prior sampling results and/or the CSM for the site/area of installation. For the most part SVOCs and PAHs were not appropriate to include. A sentence to that effect has been added to the text.

**Comment 14:** **Page 2-13, Section 2.9.4, RSA-147/148/149 Supplemental Phase 2b RCRA Facility Investigation, Fourth Bullet, Fourth Sentence:** Please revise the sentence by changing “polyethylene diffusion bad samplers” to “polyethylene diffusion bag samplers”.

**Response 14:** Text will be corrected per the comment

**Comment 15:** **Page 2-13, Section 2.9.4, RSA-147/148/149 Supplemental Phase 2b RCRA Facility Investigation, Fourth Bullet, Last Sentence:** This sentence indicates that four new monitoring wells were sampled in October 2014 with disposable bailers and were analyzed for TCL VOCs, TCL pesticides, PCBs TAL metals, TDS, TOC, chloride, nitrate, sulfate, dissolved gases, DHC, alkalinity, and dissolved iron (ferrous/ferric). Bailer use can disturb the well water in such a way as to result in questionable data related to VOCs, metals, dissolved gasses, and other parameters. It is unclear as to why bailers were used to sample these four wells instead of using low-flow techniques. Please clarify if bailers were actually used. If these wells were sampled using the bailer method, they may need to be resampled using approved low-flow techniques for more reliable results.

**Response 15:** See response to Specific Comment 12 regarding the analytical suite. Disposable bailers were selected for sampling instead of low flow methods given the likelihood of encountering DNAPL in these wells.

**Comment 16:** **Page 2-14, Section 2.9.4, RSA-147/148/149 Supplemental Phase 2b RCRA Facility Investigation, RSA-149, Second Bullet:** Please revise this bullet by clarifying why TCL SVOCs, PAHs and low level PAHs were not sampled in the newly installed wells.

- Response 16:** See response to Specific Comment 12. Note also that this well is associated with the RSA-117 site which is responsible for its own groundwater.
- Response 17:** **Page 2-14, Section 2.9.4, RSA-147/148/149 Supplemental Phase 2b RCRA Facility Investigation, RSA-149, Last Paragraph:** The last paragraph indicates that a synoptic water level sweep of all piezometers and monitoring wells within RSA-147/148/149 were completed in late September and early October 2014. Please revise this paragraph by referencing the location of these data from the water level sweep.
- Response 17:** The text has been revised to reflect that measurements were made in 784 of the wells and piezometers existing at that time within the three units, with reference made to the potentiometric map presented in Chapter 3 (Figure 3-8).
- Comment 18:** **Page 2-15, Section 2.10, Summary of Available Data, Top Bullet:** The bullet states, "Multiple dye traces have been completed by the Army and NASA, which serve to describe groundwater flow velocities and vectors from source areas to downgradient well and springs." Please revise this bullet by referencing the location/figure for these dye traces.
- Response 18:** The text has been revised to include a citation to Table 2-1 and that the results are discussed in Chapter 3.
- Comment 19:** **Page 3-6, Section 3.3.1.1 Overburden:** This section states that the maximum depth to bedrock was observed at well MC-MW-051D near Indian Creek in the eastern portion of MSFC, however Indian Creek is on the western portion of MSFC. Please revise report to clarify this discrepancy.
- Response 19:** Text revised to reflect it is in the western portion of MSFC per comment.
- Comment 20:** **Page 3-11, Section 3.3.3.1, Surface Karst Expression, Second Paragraph, First Sentence:** Please revise the sentence by changing "Figure 3-6" to "Figure 3-7".
- Response 20:** Text corrected per comment.
- Comment 21:** **Page 3-14, Section 3.4.1.1, Shallow Groundwater, Second Paragraph, First Sentence:** This sentence states, "Figure 3-8 presents the potentiometric surface for the shallow unconfined, water table aquifer based on synoptic measurements collected in September and October 2014." This potentiometric surface is based on measurements from the dry season. A figure showing the potentiometric surface during the wet season should be considered because it would contrast the different flow patterns of the dry season. By presenting wet and dry season potentiometric surface maps, they should agree with associated contaminant plumes as shown in Section 5. Please revise the report by adding a wet season potentiometric surface map. If a synoptic water level measurement has not been performed for the wet season to date, the Army should perform one and revise the RFI Report accordingly.

Additionally, there appears to be a typo on the dashed 560-foot contour to the south on Figure 3-8. The dashed contour is indicated by a 600-foot contour. Please revise the figure by changing the 600-foot contour to a 560-foot contour.

**Response 21:** A wet season potentiometric map has been added, using synoptic water levels measured in February 2017. This map has been contoured with 5-ft major contours and 1-ft supplemental contours. The 2014 dry season map has been revised to include 1-ft contours as needed. The label for the 560-ft contour has been corrected per the comment.

**Comment 22:** **Page 3-24, Section 3.4.3, Aquifer Geochemistry, First Full Paragraph, Last Sentence:** Please revise the sentence by changing “greater23” to “greater”.

**Response 22:** Text corrected per comment

**Comment 23:** **Page 4-12, Section 4.4.1, Chemicals in Groundwater, First Sentence:** The sentence indicates the parameters that were analyzed for in groundwater at RSA-147/148/149. Please refer to Specific Comment Nos. 13 and 16 and revise accordingly.

**Response 23:** See responses to Specific Comments 13 and 16.

**Comment 24:** **Page 4-12, Section 4.4.1 Chemicals in Groundwater:** Groundwater samples were analyzed for a suite of chemical parameters including nitroaromatic compounds (e.g., TNT). However, HMX and RDX are major explosive constituents but are classified as nitramines. Please clarify that nitroaromatic compounds are not the only major explosive compounds investigated.

**Response 24:** The text has been revised [globally] to change “nitroaromatic compounds” to “explosive compounds”.

**Comment 25:** **Page 4-14, Section 4.4.2, Chemicals in Surface Water, First Paragraph, First Sentence:** The sentence states, “RSA-147/148/149 surface water samples were also analyzed for TCL VOCs, pesticides, PCBs, nitroaromatic compounds, perchlorate, TAL metals, chemical agents, and other miscellaneous and general chemistry parameters.” Table 4-3 lists TCL SVOCs that were also analyzed in RSA-147/148/149 surface water. Please revise the sentence to include TCL VOCs.

**Response 25:** The text has been revised per the comment.

**Comment 26:** **Page 4-16, Section 4.5.4, Subarea 1, Indian Creek:** Indian Creek Subarea is stated to be fed primarily by surface water runoff from Betts Spring Branch and a number of perennial springs. This subarea lies particularly within RSA-149 and is fed by perennial springs. However, Betts Spring Branch is a separate watershed, primarily along the western boundary of RSA and beyond. Along with perennial springs, the Indian Creek Subarea is fed

primarily from headwaters and tributaries that extend over eight miles north of RSA. Please clarify why Betts Spring Branch is the primary feed to Indian Creek.

**Response 26:** The reference to Betts Spring Branch is in error. The text has been revised accordingly.

**Comment 27:** **Page 5-2, Section 5.1 DNAPL Occurrence:** This section states that DNAPL is “suspected” when concentrations exceed 10% of the contaminants solubility in water. However, based on the logic provided elsewhere in the report, DNAPL presence is expected when concentrations are greater than 10% and are suspected at concentrations exceeding 1%. Please review the report, and revise as necessary to correct this discrepancy.

**Response 27:** Concentrations in excess of 10% of the solubility generally indicate the potential for DNAPL in the vicinity of the monitoring wells (possibly upgradient along a flowpath), whereas concentrations in excess of 1% of the solubility are indicative of DNAPL presence at that location. These distinctions will be clarified in the Rev 1 RFI document.

**Comment 28:** **Page 5-3, Section 5.1, DNAPL Occurrence:** The first paragraph states that Figure 5-2(a/b) indicate that the majority of DNAPL indications are restricted to the shallow flow component. However, the last sentence of this paragraph is confusing as it states that “*The shallow DNAPL areas show that with few exceptions, the DNAPL is restricted to the shallow flow component (i.e. there are no observed DNAPL indications within the shallow DNAPL area polygons (Figure 5-2a).*” Please consider rewording this sentence, or revising it to state “... i.e. there are few observed deep DNAPL indications within the shallow DNAPL area polygons (Figure 5-2a).”

**Response 28:** The suggested language will be used in the Rev 1 report.

**Comment 29:** **Page 5-5 Section 5.2 Dissolved Phase Concentration:** The first bullet of the third paragraph states that figures both shallow and deep for each chemical with an exceedance are provided in order to determine the lateral extent. The Army has classified groundwater into two hydrostratigraphic units (HSU), shallow (less than 120 feet (ft)) and deep (greater than 120 ft). However, HSUs should be subdivided based on geologic characteristics including, but not limited to, permeability and porosity. Therefore, based on the geology at RSA, splitting the subsurface into 3 HSUs may more accurately depict the true groundwater flow regimes. The overburden layer rarely extends below 100 feet, and flow in this layer will follow a more traditional flow pattern governed by dispersion, diffusion, and advection. Flow in deeper units tends to follow preferential flow paths as indicated by Figure 3-8 through 3-12. Please clarify why the shallow bedrock unit comprises both residuum and shallow bedrock.

**Response 29:** Disagree. There is no merit in changing the aquifer subdivisions from the two utilized, which has been consistently applied in all of the groundwater unit

RFIs. Although the 120-ft cutoff may seem arbitrary, it fits the geochemical stratification observed by the Army and NASA that distinguishes active versus inactive flow. The geochemical transition in turn is dependent on the permeability and litho-stratigraphy. In that regard, these two factors are at least generally applied.

All flow in bedrock, whether shallow (<120 ft) or deep follows preferential flowpaths. However, as documented by the continuous water level monitoring in these groundwater units and others, the shallow bedrock and overburden are hydraulically interconnected and respond in like manner to recharge events. As described in detail in the Sitewide Karst ROF (Shaw, 2002), the overburden serves as both a source of recharge and a pressure relief to the bedrock aquifer component. This is reinforced by the similar geochemical signature and the relief of the overburden-interface contact. The pinnacle and cutter topography of the bedrock surface puts overburden wells completed in a cutter at the same elevation horizon as a bedrock well completed in a pinnacle.

**Comment 30:** **Page 5-7, Section 5.2, Cross Sections, First Paragraph, Fifth Sentence:** The sentence references Figures 5-3, 5-4, and 5-5. The font is not legible on the inset figure showing the cross-section locations at the top right of each figure. The font for the well locations on the cross-section locations are too small to read. Please revise the figure by either enlarging the font for the well locations on the inset figure or add another figure where all the fonts for the well locations are legible.

**Response 30:** With a refined focus on the exposure unit scale preferred by ADEM, the unit-wide cross sections (Figures 5-3, 5-4, 5-5) no longer have a place and will not be included in the Rev 1 RFI.

**Comment 31:** **Page 5-7, Section 5.2, Cross Sections, First Paragraph, Fifth Sentence:** The sentence references Figures 5-3, 5-4, and 5-5. It appears that the nature and extent of contamination (i.e., benzene, chlorobenzene, 4,4'-DDD, alpha-BHC, and dieldrin) to the northeast, east, and southeast of well 147-RS2249SD has not been determined as shown on Figure 5-5 (see F-F' Cross-Section) and Figure 5-8b. Additionally, the groundwater flow in the area of well 147-RS2249SD is to the east and southeast as shown on Figure 3-8. Additional information should be provided to determine the depth of contamination and the extent of contamination to the northeast, east and southeast of well location 147-RS2249SD. Once the nature and extent of contamination has been determined, the RFI Report should be revised accordingly.

**Response 31:** See response to Specific Comments30. This comment further focuses on the depth of contamination at RSA-117 (where 147-RS2249S, D are located). The responsibility for delineation of extent of groundwater contamination lies with the surface media site; no further discussion or investigation on the part of the groundwater unit is required.

- Comment 32:** **Page 5-9, Section 5.2.1.1, TCE, Second Paragraph:** Distinct TCE plumes are said to be related to surface media sites. Ten surface media sites in upgradient positions are listed including RSA-033 and RSA-057. RSA-033 and RSA-057 are No Further Action Sites. Although RSA-057 is still a concern for groundwater, the site was addressed for arsenic. Please revise this paragraph by stating how these sites are considered sources of TCE plumes.
- Response 32:** The entire Chapter 5 has been replaced in the Rev 1 RFI with a focus on the exposure unit scale per ADEM and those sites/plumes for which the groundwater units have responsibility. The RSA-122/56/139/57 plume area falls under RSA-147 and a more thorough presentation of groundwater in that plume area is presented in the Rev 1 document. As a result, the cited text no longer exists and the comment, though noted, is moot.
- Comment 33:** **Page 5-10, Section 5.2.1.1, TCE, Fourth Paragraph:** Surface water samples exhibited TCE correlating to spring locations. As evident, surface water samples exhibited even higher TCE concentrations at some locations. To address delineation of these points, the Army should further assess surface water and springs in the Integrated Operable Unit investigations.
- Response 33:** Comment noted.
- Comment 34:** **Page 5-11, Section 5.2.1.2, 1,1,2,2-Tetrachloroethane (TeCA):** This section identifies TeCA as a solvent and degreasing agent used at RSA and as a minor impurity in commercial grade TCE. However, the report does not identify TeCA as a synonym of Acetylene Tetrachloride which was used in the decontaminating process for Mustard Gas. This is a potential source particularly in the MSFC-034 area. Please include the relationship between TeCA and the chemical agent manufacturing process in the revised RFI Report.
- Response 34:** Agreed. The text section referenced in the comment no longer exists in the revised document. This information have been added to 1,1,2,2-TeCA discussions in Section 4.5 and 5.8.3.1.
- Comment 35:** **Page 5-11, Section 5.2.1.1, TCE, Top Paragraph, Last Sentence:** The sentence states, "Consequently, TCE, the most ubiquitous contaminant in groundwater, is delineated from a groundwater unit-scale perspective." Please refer to General Comment No. 2 and revise the RFI Report accordingly.
- Response 35:** See response to General Comment 2.
- Comment 36:** **Page 5-13, Section 5.2.1.2, 1,1,2,2-Tetrachloroethane, Top Paragraph, Second Full Sentence:** The sentence states, "F10-RS545 lies upgradient of RSA-010 sources along a mapped fault and but was a primary point of ..." The sentence appears awkward. Please revise the sentence to read correctly.
- Response 36:** The entire Chapter 5 has been replaced in the Rev 1 document, such that this comment is moot.

- Comment 37:** **Page 5-13, Section 5.2.1.2, 1,1,2,2-Tetrachloroethane, Top Paragraph, Last Sentence:** The sentence states, “Therefore, this deep plume may reflect local (RSA-010 sourcing, but is more likely sourced from upgradient sources such as MSFC-034.” It appears that a deeper well along with other strategic wells should be installed to determine the sourcing and the nature and extent. Once the wells have been installed, sampled, and analyzed, the RFI Report should be revised accordingly.
- Response 37:** Disagree. Documentation of sourcing of groundwater contamination is not an objective of this RFI. Since RSA-010 lies in downgradient position within the RSA-148 unit, contamination observed in RSA-010 wells is at least in part a reflection of multiple upgradient sources including MSFC-034 (CT), RSA-249 (TeCA), and the NASA SE plume (TCE, other). Dye tracing confirmed that dye injected in the vicinity of MSFC-034 was detected in wells or springs within or downgradient of RSA-010. Similarly, dye injected in the SE plume area of NASA MSFC was detected within/downgradient of RSA-010. While this is acknowledged, all of these contributions follow discrete flowpaths in the bedrock that are beyond resolution and certainly not something that would be better determined by installation of additional monitoring wells as suggested. In each case the responsibility for delineation lies with surface media sites (MSFC-034, RSA-249, RSA-010, NASA-MSFC). The need to discern sourcing to RSA-010 is then an element of the delineation of extent for each of these surface media sites and not the groundwater unit.
- Comment 38:** **Page 5-15, Section 5.2.1.3, Chlorobenzene, First Full Paragraph, Fourth Sentence:** Please revise the sentence by changing “RSA-1175-2b” to “RSA-117”.
- Response 38:** The entire Chapter 5 has been replaced in the Rev 1 document, such that this comment is moot.
- Comment 39:** **Page 5-15, Section 5.2.1.3, Chlorobenzene, First Full Paragraph, Seventh Sentence:** This sentence states, “Although DNAPL appears to have migrated vertically to depths of nearly 300 feet within the deep groundwater at RSA-117, as described previously, the bedrock is relatively impermeable such that the DNAPL appears contained.” The rest of the paragraph goes on to discuss downgradient conditions of lateral extent and indicates the nearest downgradient springs along faulting are about 7800 feet (i.e., 1.48 miles) to the southeast. The last sentence in the paragraph states, “Consequently, the extent of CBZ appears to have been delineated on the groundwater unit scale.” The Department does not agree that the extent of contamination has been determined or appears contained in that the distances used between the source and monitoring points is excessive and the depth of contamination has not been determined (see General Comments No. 1-4). Additional drilling of monitoring wells to determine the nature and extent (i.e., vertical and lateral extent) should be performed to tighten up the contaminant plumes. Once the wells have been installed, sampled, and analyzed, the RFI Report should be revised accordingly.



- Response 39:** See response to General Comments 1-4. The delineation and remedy of groundwater at RSA-117 is the responsibility of the RSA-117 surface media site. Therefore, no further investigation is required on the part of the groundwater unit.
- Comment 40:** **Page 5-15, Section 5.2.1.3, Nature and Extent of CBZ, First Paragraph, Second and Third Sentences:** The sentences state, "The extent of CBZ is delineated, as described above, by multiple downgradient and cross-gradient sampling locations where CBZ was not detected or was detected below its PSV. Cross-Sections A-A', B-B', and C-C' (Figures 5-3 and 5-4) transect the CBZ plume areas and document the delineation of contamination in the downgradient direction." The remainder of the paragraph discusses the extent of CBZ contamination to the south based on spring and well sampling. This paragraph does not present the information from Figure 5-5 in Cross-Section F-F' (See Specific Comment No. 31). Section 5.2.1.3 does not provide definitive data or information to determine nature and extent of contamination both laterally or vertically. Please refer to General Comment No. 3 and Specific Comment No. 31 and revise the RFI Report accordingly.
- Response 40:** See response to General Comments 3 and Specific Comment 31.
- Comment 41:** **Page 5-15, Section 5.2.1.3 Chlorobenzene, Second Paragraph:** The report states, "Three deep groundwater wells are located in the northern part of RSA1175-2b". Revise the sentence to state "Three deep groundwater wells are located in the northern part of RSA-117 as seen on Figure 5-2b."
- Response 41:** Agree, however, the entire Chapter 5 has been replaced in the Rev 1 document, such that this comment is moot.
- Comment 42:** **Page 5-15, Section 5.2.1.3 Chlorobenzene, Second Paragraph:** Chlorobenzene has been identified in deep groundwater. Downgradient springs (RSP-1544 listed twice) along the fault block trend used in delineation are listed as 7,800 feet to the southeast. Please clarify if the other spring is RSP-1543. Also, fault blocks have been shown to impede but not necessarily prohibit groundwater flow. Please revise the RFI Report by indicating whether chlorobenzene has been detected in springs (RSP-1504 and RSP-1506) less than 2,000 feet to the east across fault blocks but within the discharge zone.
- Response 42:** Agree, the text should have read RSP-1543 and RSP-1544. The springs to the east of RSA-117, RSP-1504 and RSP-1510a, were both non-detect for chlorobenzene, as indicated on Figure 5-8a and 5-8b. The distal springs were included to document that CBZ contamination associated with RSA-117 does not discharge within the same fault block in downgradient positions.
- Comment 43:** **Page 5-16, Section 5.2.1.4, Carbon Tetrachloride, First Paragraph, Fourth Sentence:** The sentence states, "All groundwater exceedances occur within the shallow groundwater zone; no deep groundwater exceedances were detected." Figures 5-9a and 5-9b indicate that the nature and extent of

contamination has not been determined at depth. In Figure 5-9b there is only one monitoring well located in the plume area that indicates a non-detect at depth. It is difficult from these figures to determine which deep well is indicated in Figure 5-9b. Assuming from Figure 2-4 that the deep well is MC-MW00-403Da,b, this well is located near the central plume and somewhat in a position north of the main plume with no detects. However, Figure 3-8 indicates that the groundwater is flowing in several directions at that location (i.e., southeast, south, and southwest) depending on where you are located in the plume itself. There are no deep wells to the southern end of the plume. Deep well(s) should be installed to the south/southeast/southwest of the carbon tetrachloride (CT) plume to determine the depth of contamination. Once the wells have been installed, sampled, and analyzed, the RFI Report should be revised accordingly.

**Response 43:** The comment is referencing CT contamination within MSFC-034. MSFC-034 has the responsibility for groundwater delineation and remedy and is not the subject of the groundwater unit RFI. Any further investigation will need to be addressed by the surface media site.

**Comment 44:** **Page 5-17, Section 5.2.1.4, Carbon Tetrachloride, First Full Paragraph, Second Sentence:** The sentence states, "CT did not exceed the PSV in deep groundwater (Figure 5-9b) at any of the sample locations within RSA-147/148/149." It is unclear as to what is meant by "any of the sample locations" did not exceed the PSV in deep groundwater. Please clarify if all the deep wells were sampled for carbon tetrachloride in RSA-147/148/149. Please see Specific Comment No. 43 and revise the RFI Report accordingly.

**Response 44:** See response to Specific Comment No. 43. Additionally, all of the deep groundwater wells have been sampled for VOCs, which includes CT.

**Comment 45:** **Page 5-17, Section 5.2.1.4, Carbon Tetrachloride, Second Full Paragraph:** This paragraph indicates there is a spring (RSP-0780a) near Indian Creek at the southwestern MSFC boundary and an associated surface water body that has CT above the PSV. Dye tracing indicated that the source of CT came from MSFC-034 and/or MSFC-027. Considering the discussions in Specific Comment Nos. 43 and 44, it would indicate that there may be a deeper flow component that connects MSFC-34 and 027 to the springs. Please refer to Specific Comment Nos. 43 and 44 and General Comments No. 1-4 and revise the RFI Report accordingly.

**Response 45:** See responses to General Comments 1-4 and Specific Comments 43-44. Connections between MSFC-027 and MSFC-034 and the downgradient springs is verified by the dye tracing although the exact flowpath is (and will remain regardless of installation of additional wells) beyond resolution. This does not imply that a deeper flowpath exists that has been missed.

**Comment 46:** **Page 5-17, Section 5.2.1.4, Carbon Tetrachloride, Nature and Extent of CT:** The Department does not agree with the nature and extent as described

in this section. Please refer to Specific Comment Nos. 43, 44, and 45, and General Comments No. 1-4 and revise the RFI Report accordingly.

**Response 46:** See responses to General Comments 1-4 and Specific Comments 43-45.

**Comment 47:** **Page 5-18, Section 5.2.1.4, Carbon Tetrachloride, Nature and Extent of CT, Top Paragraph, Fourth Sentence:** The sentence states, "CT was not detected or was detected below the PSV in all of the downgradient-most wells; these southernmost wells lie south of the key springs within the groundwater integration and discharge area near Huntsville Spring Branch." Please revise this section by defining what "groundwater integration" represents. Additionally, please revise this section by clarifying which downgradient-most wells were selected and sampled to determine the extent of contamination and also identify the "key springs" that were noted.

**Response 47:** Flowpaths and plumes originating within upgradient source areas within RSA-147, -148, and the eastern half of RSA-149 converge in the southern downgradient portions of the units (within and south of RSA-010, -060, and -053) such that plumes become "integrated" in this area. The entire Chapter 5 has been replaced in the Rev 1 document so it is unlikely this text will be repeated. However, use of the term "groundwater integration" will be accompanied by explanation to assist the ADEM reviews.

**Comment 48:** **Page 5-18, Section 5.2.1.5, Tetrachloroethene, First Paragraph, Fourth and Fifth Sentences:** The sentences states, "In surface water, PCE was detected in 41 of the 81 samples analyzed and exceeded the surface water PSV (0.603 µg/L) in 20 of those samples. Figure 5-10a presents the distribution of PCE detected in the shallow groundwater and surface water." Figure 5-10a indicates that the Preliminary Screening Value for PCE is 5 µg/L and not 0.603 µg/L as presented in section 5.2.1.5. Please revise the figure by indicating the correct Tetrachloroethene (PCE) PSV for surface water. Please review all figures for similar discrepancies and revise accordingly.

**Response 48:** Comment noted.

**Comment 49:** **Page 5-18, Section 5.2.1.5, Tetrachloroethene, First Paragraph, Fifth Sentence:** The sentence states, "Figure 5-10a presents the distribution of PCE detected in the shallow groundwater and surface water." The shallow PCE contamination detected at RSA-249 does not appear to be defined to the northwest. There are no apparent hydropunch sampling locations or monitoring wells within a reasonable distance in the northwest direction. The direction of flow, according the Figure 3-8 appears directly south. There are no deep wells in the vicinity of RSA-249 to determine the vertical extent of contamination.

It is unclear in this section if RSA-249 has been investigated appropriately to determine nature and extent of contamination. Additional information should be provided in such a way as to determine the lateral and vertical extent of

contamination. Once the information has been provided, the RFI Report should be revised accordingly.

It should be noted that there are other shallow wells that have been determined to have concentrations exceeding the PCE PSV 5 µg/L. The Army should also evaluate if these exceedances have been evaluated at depth (e.g., south of RSA-059, in the area of RSA-052, and other areas) as shown on Figure 5-10a. The depth of contamination should be evaluated for each plume area that has no deep wells installed in the vicinity of the plume. It appears the additional information should be provided to determine the depth of contamination in the areas noted above. Once the information has been provided, the RFI Report should be revised accordingly.

**Response 49:** Comment noted.

**Comment 50:** **Page 5-18, Section 5.2.1.5 Tetrachloroethene, Fifth Sentence:** Monitoring Well H62-RS047 (not labeled in Figure 5-10a), but shown on Figure 5-4, indicates a “Green color” font in the cross-section D-D’. This green color font indicates that the monitoring well ID in cross-section/shaded cell in the insert table is detected below PSV. However, the Cross-Section D-D’ data indicate that H62-RS047 has a concentration of PCE of 22.9 µg/L which is above the PCE PSV of 5 µg/L. Please revise Figure 5-4 by changing the green font to red font.

Figure 5-10a indicates that the well location H52-RS751 has concentrations of PCE greater than the PSV; however, the same well on Figure 5-5 on Cross-Section E-E’ show green font indicating PCE below PSVs. The Cross-Section E-E’ chemical result data indicate that monitoring well H52-RS751 has a concentration of 7.1 µg/L. Please revise Figure 5-5 by changing the green font to red font. Please review all figures for similar discrepancies and revise the figures accordingly.

**Response 50:** With the complete reformatting of Chapter 5 and focus on only those plumes for which the groundwater unit has responsibility, the cross section figures (Figures 5-4, 5-5) will be deleted from the Rev 1 document.

**Comment 51:** **Page 5-19, Section 5.2.1.5, Tetrachloroethene, Second Paragraph:** This paragraph states, “As shown on Figure 5-10b, PCE does not appear to have significantly impacted deep groundwater. The one concentration that exceeds the PSV in the deep groundwater flow zone was found in Z-RS1232D (28 µg/L). This well is located in the northern part of RSA-117 (Figure 5-10b). The deep exceedance is likely the result of solvent use at RSA-117.” This paragraph does not present any definitive data or information showing the nature and extent of PCE contamination associated with this well at depth. In addition, the paragraph states that the result of this deep contamination is likely the result of solvent used at RSA-117. There are no other wells indicated on Figure 5-10a or Figure 5-10b that show PCE contamination at RSA-117. Please clarify this discrepancy and revise accordingly.

The deep flow patterns for this area are not clear. For example, flow patterns shown on Figure 3-8 indicate a possible easterly flow and possible flow toward the faulting shown on Figure 5-4 to the east of monitoring well Z-RS1232D. Additionally, there are no other deep wells to the north or east (i.e., possible direction of flow) to define the lateral extent in that direction. Additional wells should be installed in such a way as to determine the lateral and vertical extent of contamination. Once the wells have been installed, sampled, and analyzed, the RFI Report should be revised accordingly.

**Response 51:** RSA-117 has the responsibility for delineation and remedy of groundwater and any further investigation will need to be conducted under that unit. It should be noted however, that flow vectors within the bedrock are controlled by the combination of hydraulic head and the orientation of discrete stratigraphic and structural features. The orientation and head are feature specific. As a result the gradient of the water table is a poor indicator of the flow vectors in the rock, especially at depth.

**Comment 52:** **Page 5-20, Section 5.2.1.5, Tetrachloroethene, Top Paragraph, Last Sentence:** This sentence indicates that PCE in groundwater is delineated from a groundwater unit-scale perspective. The Department does not agree with the Army's assertion that PCE has been defined on a groundwater unit-scale perspective based on Specific Comment Nos. 48 through 51. Please refer to General Comment No. 1 and Specific Comment Nos. 48 through 51 and revise accordingly.

**Response 52:** See responses to General Comments 1 and Specific Comments 48-51.

**Comment 53:** **Page 5-20, Section 5.2.1.6, Benzene:** Benzene appears to be a breakdown byproduct of CBZ and also appears to be associated with the CBZ plumes within RSA-147/148/149. Please refer to Specific Comment Nos. 39 and 40 about the nature and extent of CBZ and its association with benzene and revise the RFI Report accordingly.

Monitoring Well 147-RS2249SD indicates benzene, CBZ, 4,4'-DDD, alpha-BHC, and dieldrin contamination in the deep monitoring zone. It appears that the nature and extent of these contaminants to the northeast, east, and southeast of well 147-RS2249SD has not been determined as shown on Figure 5-5 (see F-F' Cross-Section) and Figure 5-8b and 5-11b. Please also refer to Specific Comment No. 31. Additionally, the groundwater flow in the area of well 147-RS2249SD is to the east and southeast as shown on Figure 3-8. Additional wells should be drilled to determine the depth of contamination and the extent of contamination to the northeast, east and southeast of well location 147-RS2249SD. Once the nature and extent of contamination has been determined, the RFI Report should be revised accordingly.

**Response 53:** See responses to Specific Comment Nos. 31, 39, and 40. The comment focuses on delineation of contamination at RSA-117. However, the responsibility for delineation and remediation of groundwater lies with the

RSA-117 site. The need for additional wells should be addressed within the context of the RFI for that unit.

**Comment 54:** **Page 5-21, Section 5.2.1.6, Benzene, First Full Paragraph, Second Sentence:** Please revise this sentence by changing “Figure 2-1” to “Figure 2-4”.

**Response 54:** The entire Chapter 5 has been replaced in the Rev 1 RFI document such that this comment is moot.

**Comment 55:** **Page 5-21, Section 5.2.1.6, Benzene, Nature and Extent of Benzene, Fourth Sentence:** This sentence states, “Cross sections A-A’, C-C’, and D-D’ (Figures 5-3 and 5-4) transect the benzene exceedances areas and illustrate that the extent of PSV exceedances is defined in the downgradient direction.” This sentence should also include Cross section F-F’ (Figure 5-5) because of Monitoring wells 147-RS2251SD and 147-RS2249SD and their associated benzene contamination. Please refer to Specific Comment No. 53 and revise the RFI Report accordingly.

**Response 55:** See response to Specific Comment No. 53.

**Comment 56:** **Page 5-22, Section 5.2.1.6, Benzene, Nature and Extent of Benzene, Top Paragraph, Last Sentence:** This sentence indicates that benzene in groundwater is delineated from a groundwater unit-scale perspective. The Department does not agree with the Army’s assertion that benzene has been defined on a groundwater unit-scale perspective based on Specific Comment Nos. 53 and 55. Please refer to General Comments No. 1-4 and Specific Comment Nos. 53 and 55 and revise accordingly.

**Response 56:** See response to Specific Comment Nos. 53 and 55.

**Comment 57:** **Page 5-22, Section 5.2.1.7, Vinyl Chloride:** Vinyl chloride (VC) appears to be a reductive dechlorination product of TCE and also appears to be associated with the TCE plumes within RSA-147/148/149. Additionally, VC is associated in deep wells at RSA-117 and RSA-053. Please refer to General Comments No. 1-4 and Specific Comment No. 32 about the nature and extent of TCE and its association with vinyl chloride and revise the RFI Report accordingly.

**Response 57:** See responses to General Comments No. 1-4 and Specific Comment No.32.

**Comment 58:** **Page 5-26, Section 5.2.1.9, Top Paragraph, Last Sentence:** Please revise the sentence by changing “chloroform” to “MC”.

**Response 58:** The entire Chapter 5 has been replaced in the Rev 1 RFI document such that this comment is moot.

**Comment 59:** **Page 5-26, Section 5.2.1.9:** This section does not have a “Nature and Extent of Methylene Chloride” write up. Please revise this report to include text

about the nature and extent of MC. The deep MC contamination within the RSA-117 plume should be evaluated for nature and extent similarly to other constituents that it is comingled with.

**Response 59:** The entire Chapter 5 has been replaced in the Rev 1 RFI document such that this comment is moot. Although no specific header or subsection is included, the nature and extent of MC was described in Section 5.2.1.9.

**Comment 60:** **Page 5-26, cis-1,2-Dichloroethene:** It is unclear as to why this chemical (i.e., cis-1,2-Dichloroethene) is not described under a section notation as all the other chemicals of concern have been. Please revise the report by adding a section describing cis-1,2-Dichloroethene.

**Response 60:** It appears the section callout (should have been 5.2.1.10) was left out. However, the entire Chapter 5 has been replaced in the Rev 1 RFI document such that this comment is moot

**Comment 61:** **Page 5-27, cis-1,2-Dichloroethene, First Full Paragraph:** cis-1,2-Dichloroethene (DCE) plumes are associated with plumes noted in Sections 5.2.1.1 (TCE) and 5.2.1.2. (1,1,2,2-Tetrachloroethane). Because DCE is a degradation product of TCE, please refer to Specific Comment Nos. 32 through 37 and revise the RFI Report accordingly.

**Response 61:** See responses to Specific Comment Nos. 32 through 37.

**Comment 62:** **Page 5-28, Section 5.2.1.10, 1,2-Dichloroethane:** Please revise this section by clarifying if the deep monitoring well as described in this section as having a 1,2-Dichloroethane (1,2-DCA) concentration of 8.5 µg/L is well Z-RS1232S,D,I. Because 1,2-DCA is associated with other VOCs discussed above and is associated with contamination in the deep zone in the RSA-117 area, please refer to General Comments No. 1-4 and Specific Comment Nos. 31, 39, 40, and 53 and revise the RFI Report accordingly.

Please revise the document by referencing specific wells as to their designations for easier reference in the text. Please include the specific wells designations as discussed in the text on Figures 5-6a through 5-48b and figures referenced in Appendix E. Please refer to General Comment No. 6 and revise the RFI Report accordingly.

**Response 62:** See responses to General Comments No. 1-4 and 6, and Specific Comment Nos. 31, 39, 40, and 53.

**Comment 63:** **Page 5-29, Section 5.2.1.10, VOCs Detected at Low Frequencies of Exceedance, 1,1-Dichloroethene, Fourth Sentence:** This sentence states, "This exceedance is may be the result of migration from northern sources (MSFC-034 or NASA) along flowpaths identified by dye tracing, rather than local sources (RSA-010." This sentence appears awkward and should be revised to either state "This exceedance is..." or "This exceedance may be...", but not both. Please revise accordingly. Because 1,1-Dichloroethene (1,1-

DCE) is associated with other contaminants of concern at depth, please refer to Specific Comment No. 37 and revise the RFI Report accordingly.

**Response 63:** See response to Specific Comment No. 37.

**Comment 64:** **Page 5-30, Section 5.2.1.10, VOCs Detected at Low Frequencies of Exceedance, 1,1-Dichloroethane:** This constituent is said to exceed in three shallow zone wells. A figure for these exceedances is included in Appendix E but not in the main figure section of the report like all other constituent exceedances. It is also referenced to align with deep groundwater zone plume area for 1,1,2,2-TeCA (Figure 5-7b). For consistency, a figure should be generated for 1,1-Dichloroethane or Figure 5-7b should be revised to include 1,1-Dichloroethane.

**Response 64:** The entire Nature and Extent chapter has been replaced such that the comment is moot.

**Comment 65:** **Page 5-30, Section 5.2.1.10, VOCs Detected at Low Frequencies of Exceedance, Acetone and Bromomethane:** For the acetone discussion, the paragraph should be revised to reference Figure E-7a and Figure E-7b and discuss the nature and extent of acetone. For the bromomethane discussion, the paragraph should be revised to reference Figure E-8a and Figure E-8b and discuss the nature and extent of bromomethane at depth. Please revise this paragraph accordingly.

**Response 65:** The entire Nature and Extent chapter has been replaced such that the comment is moot.

**Comment 66:** **Page 5-31, Section 5.2.1.11, Summary of Volatile Organic Compounds, Last Bullet:** This Bullet states, "All VOC contaminants are delineated in the shallow and deep flow zones at the scale of the groundwater unit by monitoring locations where concentrations are below the PSV or are not detected. Contaminant migration is being monitored in the downgradient groundwater discharge zone associated with Huntsville Spring Branch and Indian Creek." The Department does not agree with the nature and extent as described in this bullet. Please refer to General Comment No. 2 and related Specific Comments above and revise the RFI Report accordingly.

**Response 66:** See responses to General Comment No. 2 and related Specific Comments above

**Comment 67:** **Page 5-32, Section 5.2.2.1, Dibenz(a,h)anthracene:** This section references Figures 5-16a and 5-16b. Figure 5-16b should be revised to show all deep wells so that the nature and extent evaluation can be made similarly to all previous figures showing deep contamination. This figure shows only the deep wells indicating dibenz(a,h)anthracene and associated springs. Please revise the figure accordingly.



- Response 67:** Agreed. Not all the well results are shown. However, the entire Nature and Extent chapter has been replaced such that the comment is moot
- Comment 68:** **Page 5-32, Section 5.2.2.2, Naphthalene:** This section references Figures 5-17a and 5-17b. Even though Figure 5-17b does not show any naphthalene contamination above PSVs, the figure should be revised to show all deep wells so that the nature and extent evaluation can be made similarly to all previous figures showing deep contamination (see also Specific Comment No. 67). This figure shows only a few of the deep wells and associated springs. Please revise the figure accordingly.
- Response 68:** See response to Specific Comment No. 67.
- Comment 69:** **Page 5-33, Section 5.2.2.3, bis(2-Ethylhexyl)phthalate:** There are several concerns with this section and are bulleted below:
- The first sentence states, “Like methylene chloride, bis(2-Ethylhexyl)phthalate is most often present as a result of laboratory contamination and was detected in 62 of 337 groundwater samples.” This statement should not be presented as an assumption that when you detect bis(2-Ethylhexyl)phthalate that it is from laboratory contamination. The impression reading this sentence appears to assume that all 62 of the 337 groundwater samples had bis(2-Ethylhexyl)phthalate as a laboratory contaminant. This issue can be resolved by further sampling. If these wells were sampled more than once and have shown that bis(2-Ethylhexyl)phthalate is absent or below PSVs, then the assumption may be defensible; however, this section does not provide additional information to confirm if the samples were contaminated with bis(2-Ethylhexyl)phthalate. Please revise this statement to suggest in some cases that bis(2-Ethylhexyl)phthalate may be a laboratory contaminant.
  - The second through fourth sentences states, “Eight detections (7 shallow and 1 deep) exceed the MCL/PSV of 6 µg/L (Table 4-2). bis(2-Ethylhexyl)phthalate was not detected in any of the 23 surface water samples (Table 4-3). The PSV exceedances in the shallow and deep zones are depicted on Figures 5-18a and 5-18b, respectively.” It appears from Figure 5-18a that there are numerous wells (i.e., approximately 19 wells assumed from the figure; nine yellow dots, and 10 green dots) that were detected above the bis(2-Ethylhexyl)phthalate PSV of 6 µg/L. Figure 5-18a does not agree with the text that only seven shallow groundwater detections exceeded the PSV of 6 µg/L. Please revise this section by clarifying this apparent discrepancy between Section 5.2.2.3 and Figure 5-18a.
  - The third sentence states, “bis(2-Ethylhexyl)phthalate was not detected in any of the 23 surface water samples (Table 4-3).” Figure 5-18a indicates two surface water sample locations (i.e., one located south of RSA-010 and one south of RSA-101) that are above the bis(2-Ethylhexyl)phthalate PSV of 0.847 µg/L. Please revise this section by clarifying the

discrepancy between the text and Figure 5-18a. In addition, please add the surface water sampling location designations to this section if applicable.

- The fifth and sixth sentences state, “Springs integrate groundwater from both the shallow and deep flow zones; therefore, spring sampling results are presented on both figures. However, bis(2-Ethylhexyl)phthalate was not detected in any of the sampled springs.” Figure 5-18a shows two spring locations (i.e., one south of RSA-010 and one south of RSA-101) with bis(2-Ethylhexyl)phthalate greater than its PSV of 6 µg/L. Please revise this section by clarifying this apparent discrepancy between the text and Figure 5-18a. In addition, please add the spring designations to this section if applicable.
- The last sentence states, “The analyses for this compound indicate the concentrations are well within the range assumed to be the result of common laboratory contamination and, as such, the elevated results require no further evaluation.” The Department does not agree with the assertion that no further evaluation is required for bis(2-Ethylhexyl)phthalate PSV exceedances. Further sampling of these wells should be performed to assess if bis(2-Ethylhexyl)phthalate is a contaminant of concern or a laboratory contaminant. The areas of bis(2-Ethylhexyl)phthalate PSV exceedances appear to be in locations around landfills (i.e., RSA-010 and RSA-056) according to Figure 5-18a. The Army should resample the wells showing bis(2-Ethylhexyl)phthalate PSV exceedances and revise the RFI Report accordingly.
- Figure 5-18b again indicates two springs that are apparently above the bis(2-Ethylhexyl)phthalate PSV of 6 µg/L. Please refer to the fourth bullet above and revise accordingly.
- The last paragraph states, “Based on the available data, the extent of bis(2-Ethylhexyl)phthalate in groundwater and surface water within RSA-147/148/149 has been delineated.” The Department does not agree with the Army’s assertion that bis(2-Ethylhexyl)phthalate has been delineated at this time base on the bullets noted above. Please revise this section based on the bullets provided above then revise the RFI Report accordingly.
- This section references Figures 5-18a and 5-18b. Figure 5-18b should be revised to show all deep wells so that the nature and extent evaluation can be made similarly to all previous figures showing deep contamination. This figure shows only a few deep wells and the deep well that shows the bis(2-Ethylhexyl)phthalate PSV exceedance and associated springs. Please revise the figure accordingly.

**Response 69:** The entire chapter has been revised such that the comment is moot. However, bis(2-Ethylhexyl)phthalate is not a contaminant introduced by former or ongoing operational processes and in many cases is a laboratory contaminant. The statement may nonetheless be over-reaching. It is agreed that evaluation

of occurrences over time is a reasonable lines of support for this argument, assuming the contaminant is not consistently present. Caution will be used in any further discussion of bis(2-Ethylhexyl)phthalate in the Rev 1 document.

- There are apparent discrepancies between the text and figures, suggesting one or both are in error. From review of the data the correct statistics regarding this compound are as follows:

	<u>Detected</u>	<u>&gt; PSV</u>
Shallow MWs	68	9
Deep MWs	3	1
Springs	0	0
SW	0	0

- See response to bullet 2
- See response to bullet 2
- Replicate comment (4<sup>th</sup> bullet). See response to 4<sup>th</sup> bullet.
- The entire chapter has been revised. Most of the bis(2-Ethylhexyl)phthalate are located in sites for which the responsibility for delineation lies with the surface media site.
- All locations sampled for bis(2-Ethylhexyl)phthalate are supposed to be shown. However, given the apparent errors noted above, the figure may not be accurately reflecting the data.

**Comment 70:** **Page 5-33, Section 5.2.2.4, Benzo(a)anthracene:** This section references Figures 5-19a and 5-19b. Figure 5-19b should be revised to show all deep wells so that the nature and extent evaluation can be made similarly to all previous figures showing deep contamination. This figure shows only a few deep wells and the deep well that shows the benzo(a)anthracene PSV exceedance, and associated springs. Please revise the figure accordingly.

It is unclear if the nature and extent of benzo(a)anthracene has been determined near the area of monitoring well H61-RS134 (i.e., well located on the east side of RSA-061 shown on Figure 5-19a) based on the information provided in this section. Figure 3-8 shows groundwater flow to the east and southeast at well location H61-RS134. It appears that wells should be installed to the north, west/northwest, and east of well location H61-RS134 to define the nature and extent of benzo(a)anthracene and potentially other constituents associated with RSA-061. The RFI Report for RSA-061 is due February 4, 2021. Apparently, wells are not scheduled to be installed in the near future for the purpose of the RSA-061 RFI. However, in order to meet the nature and extent of contamination for benzo(a)anthracene and other potential constituents, the wells suggested above should be installed and sampled and the RFI Report should be revised accordingly.

It appears that well location F10-RS235 contains numerous contaminants above their respective PSVs (i.e., cis-1,2-Dichloroethene, vinyl chloride, benzo(a)anthracene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and 2-Nitrotoluene). It is unclear if the depth of contamination has been determined for these contaminants. According to the cross sections provided in Figures 5-3, 5-4, and 5-5, it appears that additional deep wells should be installed to determine the lateral and vertical extent of contamination to the west and south of well location F10-RS235. Once the nature and extent of contamination has been determined, the RFI Report should be revised accordingly.

**Response 70:** Disagree. The comments focus on RSA-061 and RSA-010, both of which hold the responsibility for delineation of nature and extent (and remedy) of contamination in groundwater. With the Rev 1 focus on only those areas for which the groundwater units are responsible, no further investigation or discussion is addressed or required in the RFI.

With regard to RSA-010, F10-RS235 (screened from 202-206', Mfp-5) is the deepest well of a four well cluster located along the southern boundary of RSA-010. RS235 showed cis-1,2-DCE at 114 ug/L, VC at 4.03 ug/L, both above the PSV in the most recent sample from April 2014. These concentrations remain consistent with previous sampling results in 2009, 2012, and 2013. Benzo(a)anthracene (0.06 J), benzo(b)fluoranthene (0.06 J), dibenz(a,h)anthracene (0.05 J), and Indeno(1,2,3-c,d)pyrene (0.06 J) were also present slightly above the conservative PSV. These PAHs were ND in the previous 2013 sampling results. 2-NT was also detected at 0.59 ug/L (PSV = 0.31 ug/L) which was consistent with the 2013 sampling result (0.44 ug/L).

F10-RS234 is the next deepest well screened at 217-226' (Mfp-7/MDc) which lies 546 ft downgradient of RS235 to the southwest. This well was ND for PAHs, VC, cis-1,2-DCE, and explosives. This well serves to delineate the lateral and vertical extent of contamination observed in F10-RS235.

F10-RS235 extends into the basal Fort Payne. The log for F10-RS234 which was drilled to a TD of 247', fully penetrating the MDc, showed no indications of water production at greater depth (i.e., from 225 to drilled TD) and marginal to low water production from the screened interval at 216-225'.

The mean water level elevation for F10-RS235 (561.95) is higher than in F10-RS234 (549.96) supporting that F10-RS234 is downgradient.

Resampling of F10-RS235 may refute the 2013 results and eliminate PAHs but is also likely to continue to show the presence of cis-1,2-DCE and VC slightly above the PSV since natural reductive dechlorination is ongoing. Resampling will not likely eliminate 2-NT since it was also confirmed in both 2013 and 2014 sampling events. However, as discussed above, the delineation is deemed completed by downgradient well F10-RS234.

With regard to RSA-061, three PAH compounds, (benzo(a) anthracene, benzo(b)fluoranthene, and indeno(1,2,3-c,d)pyrene, were each detected at estimated concentrations of 0.05 ug/L in H61-RS134, exceeding the PSV of 0.03 ug/L (same for each) . This well was only sampled for PAHs once in 2013. The previous PAH results were from 1996 and were ND, however, the detections limits were higher than in 2013. H61-RS134 is an OVB well screened from 55-65' and located just outside the eastern boundary of RSA-061. It is bounded by similar OVB wells H61-RS135 and H61-RS137 which lie 380' and 650' further downgradient along the flowpath. Well H61-RS757 lies 347' upgradient to the N-NW (within RSA-061 proper). There are no wells to the east of RS134, but none needed since the flow direction is to the S-SE, towards the wells listed above. ADEM comment acknowledges the prevailing gradient. PAHs are not a component of the CSM for RSA-061 (a former munitions demil and disposal area) and were not detected in any of the offset wells or any other well at RSA-061. The isolated detections in well RS134 highlight that extensive PAH plumes are not present. Further resampling of this well should be considered as part of the RSA-061 RFI to confirm or refute the presence of the PAHs.

**Comment 71:** **Page 5-34, Section 5.2.2.5, Indeno(1,2,3-cd)pyrene:** Indeno(1,2,3-cd)pyrene appears to be present in the many of the same locations as benzo(a)anthracene as indicated in Figures 5-20a and 5-20b. Because of the similarities in where indeno(1,2,3-cd)pyrene is present above PSVs, please refer to Specific Comment No. 70 and revise the RFI Report accordingly.

**Response 71:** See response to Specific Comment No. 70.

**Comment 72:** **Page 5-34, Section 5.2.2.6, Benzo(b)fluoranthene:** Benzo(b)anthracene appears to be present in the many of the same locations as benzo(a)anthracene and indeno(1,2,3-cd)pyrene as indicated in Figures 5-21a and 5-20b. Because of the similarities in where benzo(a)anthracene is present above PSVs, please refer to Specific Comment Nos. 70 and 71 and revise the RFI Report accordingly.

**Response 72:** See response to Specific Comment Nos. 70 and 71.

**Comment 73:** **Page 5-35, Section 5.2.2.6, Bis(2-Chloroethyl)ether:** The Department does not agree that the depth of contamination has been defined based on springs to the south of RSA-117. Because bis(2-Chloroethyl)ether is associated with the deep wells at RSA-117, please refer to General Comment No. 2-4 and Specific Comment Nos. 39 and 40 and revise the RFI Report accordingly.

The second paragraph references well "117-2335", please revise the paragraph by changing "117-2335" to 117-"RS2335". In addition, Figure 5-22b should be revised to show all deep wells so that the nature and extent evaluation can be made similarly to all previous figures showing deep contamination. This figure shows only a few deep wells and the deep wells that show the bis(2-Chloroethyl)ether PSV exceedance, and associated springs. Please revise the figure accordingly.

**Response 73:** RSA-117 is responsible for the delineation and remediation of groundwater at this unit. As a result, any further investigation is not the responsibility of the groundwater unit and will need to be addressed as part of the RSA-117 RFI. The Rev 1 document has been revised to focus only on those areas and plumes for which the groundwater unit has responsibility.

**Comment 74:** **Page 5-41, Section 5.2.2.13, Summary, Last Bullet:** The last bullet states, "All SVOCs are delineated at the scale of the groundwater unit." The Department does not agree that all SVOCs have been delineated. Please refer to Specific Comments Nos. 67-73 and revise the RFI Report accordingly.

**Response 74:** See response to Specific Comments Nos. 67-73.

**Comment 75:** **Page 5-41, Section 5.2.3.1, 2-Nitrotoluene:** There are several concerns with this section and are bulleted below:

- The last sentence in the second paragraph on Page 4-41 states, "A third small cluster of three locations with the exceedances occur within the RSA-57/126/139 surface media sites (Figure 5-27a)." The cluster of exceedances on Figure 5-27a indicate they are within and south of the RSA-216, RSA-225 surface media sites and not within the RSA-57/126/139 surface media sites. Please revise this section by clarifying this apparent discrepancy.
- The Department does not agree with the nature and extent of isolated 2-Nitrotoluene exceedances in surface groundwater in the following locations: 1) well located in the northwestern portion of RSA-052; 2) well location in the western portion of RSA-249; and 3) well locations near RSA-216 and RSA-225. The following sub-bullets below explain the rationale for additional wells to be installed to determine the lateral extent of contamination:
  - An additional well should be installed to the west of the PSV exceedance in well H52-RS133 (located in the northwestern portion of RSA-052). The groundwater flow shown on Figure 3-8 indicates a westerly flow. There are no wells downgradient of the PSV exceedance.
  - An additional well should be installed to the west of the PSV exceedance noted in the western portion of RSA-249. The groundwater flow shown on Figure 3-8 indicates a west/southwest flow. There are no wells downgradient and to the west of the PSV exceedance.
  - Two additional wells should be installed to the west and south of the PSV exceedances near RSA-216 and RSA-225. The groundwater flow shown on Figure 3-8 indicates a south/southeast flow. There are no wells downgradient (south) and to the west (side gradient) of the PSV exceedances.

- The deep groundwater 2-Nitrotoluene PSV exceedance in deep well F10-RS235 south of RSA-010 is associated with other contaminants that exceed their PSVs (i.e., cis-1,2-Dichloroethene, vinyl chloride, benzo(a)anthracene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene). Please refer to Specific Comment No. 70 and revise the RFI Report accordingly.
- The extent of 2-Nitrotoluene contamination in the deep zone to the east, west, and south of well MC-MW00-205Df has not been defined both laterally and vertically.

Once the nature and extent of contamination has been determined, the RFI Report should be revised accordingly.

**Response 75:** The entire chapter has been replaced such that the cited text no longer exists and the comment is moot.

- The following address ADEMs specific comments (sub-bullets) requesting additional wells:
  - Disagree. RSA-052 is responsible for the delineation of groundwater and so no further action is required on the part of the groundwater unit with respect to additional wells. However, OVB well H52-RS133 has the only explosive compound detections of all the wells installed at RSA-052, with the following PSV exceedances, all of which reflect estimated concentrations.

Well	Zone	Screen	Date	2-NT	3-NT	2,4-DNT	2,6-DNT
H52-RS133	OVB	16-36	1/28/2009	<u>0.68 J</u>	<u>0.23 J</u>	<u>0.19 J</u>	<u>0.24 J</u>

This well has been sampled three times for explosive compounds (1996, 1999, 2009) and the above listed compounds were not detected in prior sampling events with equivalent reporting limits. This well is located in the northwestern-most position within this site and the hydraulic gradient appears to be towards the west (towards the adjacent wetlands) from this well. Considering the low, estimated concentrations and low frequency of detection within this site, a plume of any magnitude is not likely to exist. Wetlands lie immediately to the west of the site and well installations would be costly if even possible to implement. Installation of an offset well to the west as suggested simply to have a non-detect result along that vector is not justifiable.

- The responsibility for delineation of groundwater contamination at RSA-249 lies with the surface media site. Since publication of the Rev 0 RFI, the RFI for RSA-249 has been completed (Rev 0 document submitted to ADEM in May 2017). As part of that effort, an additional 9 wells have been installed, including 7 interface wells and 2 shallow bedrock wells.

- While the responsibility for remedy of groundwater lies with the RSA-225 unit, the RFI for which was approved by ADEM. The responsibility for the remedy of groundwater at RSA-216 lies with the RSA-147 groundwater unit. The responsibility for delineation lies with both surface media sites. Since issuance of the Rev 0 RFI a number of further investigations have been completed which negate the need for further characterization of the 2-NT exceedance in well 225-RS1901 within the RSA-25 site. First of all, the RFI for RSA-216 has been completed (Rev 0 document submitted to ADEM in July 2016) which concluded that there are no COCs in groundwater. Eight wells were installed at RSA-216 as part of that effort. The February 2017 heads measured in the new RSA-216 and other area wells document a potentiometric high underlies RSA-216 such that the gradient across RSA-225 is to the SE. As a result, the exceedance in RS1901 is bounded by the ND result in downgradient well 225-RS1902 to the SE. Second, the three wells with 2-NT detections in this area (wells 225-RS1901, -RS2471, -RS2044) were resampled in January 2017 as part of the RSA-147 RFI in response to ADEM comment. The resampling did not confirm the presence of 2-NT (all results were ND). 2-NT was never a part of the CSM for RSA-216 or RSA-225, so these results are confirmation of the CSM. As a result, the delineation is considered complete in this area and no further well installation is warranted.
- See response to Specific Comment 70.
- 2-NT was only detected in three locations and only exceeded the PSV in two wells, one of which was shallow (H62-RS067) and one deep (MW00-205Df). RS067 has been analyzed for explosives many times and the most recent result (0.42 ug/L) was the only detection and then, only slightly above the PSV (0.31). MW00-205Df is the deepest interval of a 6-port FLUTE well that has only been sampled once for explosives in 2012. 2-NT was not detected in any of the other five shallower intervals at this location. Installing additional deep wells to bound low, estimated concentration level exceedances in a complex bedrock setting is unjustifiable and ludicrous to consider. It should be pointed out that this entire area is within the fan arc of the active range and access is spotty at best. It took nearly three years to gain access to install the RS1978 well and NASA suffered the same delays in installing the other two FLUTE wells. All 6 ports in the MW00-205D FLUTE well were resampled in January 2017 (for specific pesticides and explosives) in response to this comment as part of the RSA-148 RFI. The results were non-detect for 2-NT in all six ports, including MW00-205Df.

**Comment 76:** Page 5-42, Section 5.2.3.2, Nitroglycerin: There are several concerns with this section and are bulleted below:



- The extent of nitroglycerin contamination in the deep zone south of well F10-RS488 has not been defined to the south or vertically.
- The extent of nitroglycerin contamination in the deep zone to the east, west, and south of well MC-MW00-205Df has not been defined both laterally and vertically.
- On Page 5-43, Section 5.2.3.2, second full paragraph, last sentence it states, “Both exceedances are delineated at the scale of the groundwater unit by the existing well control.” Please revise this section by clarifying the wells that are delineating the deep groundwater PSV exceedances. Please refer to the two bullets above and revise the section accordingly.
- Last paragraph of this section states an exceedance in springs and surface water was not detected. However in 2013, a sample from spring RSP-828 indicated a 2-NT concentration of 8.03 µg/L, which is over 25 times the PSV of 0.31 µg/L. This location appears on Figure 5-27b. Although no other constituent exceeded a PSV at this location, comment on the detection of 2-NT.

Once the nature and extent of contamination has been determined, the RFI Report should be revised accordingly.

**Response 76:**

Delineation and remedy for GW are the responsibility of RSA-010 and no further actions are warranted for the groundwater unit RFI. F10-RS488 is screened from 94-154' (Mfp-1 through Mfp-4) and is the deepest of a four-well cluster in the SW corner of RSA-10. VC (10.3), cis-1,2-DCE (181), 2,6-DNT (0.17 J, PSV = 0.11), 3-NT (0.25 J, PSV = 0.17), and nitroglycerin (0.74 J, PSV = 0.70) exceed the PSV. The explosive compound hits from December 2013 represent the only analysis for explosives. Further, F10-RS488 has been closed such that confirmation resampling is not an option. In the case of RS488, three fractures were identified in the drilling (92-93.5, 94.5-95', 129-130' and 152-153'). The long screened interval was intended to span all three intervals such that it is uncertain where the contamination is entering the borehole. It should not be assumed that the contaminated groundwater sampled in this well is coming from the deepest of these features within the screen interval. The PSV exceedances observed in F10-RS488 are vertically delineated by F10-RS234 (screened from 217-226'; Mfp-7/MDc) located 605 ft to the S-SE. This well was sampled for explosive compounds in January 2009 and none were detected. Cis-1,2-DCE and VC were ND in RS234. RS234 lies at the last accessible downgradient position adjacent to the wetlands – no further delineation is possible or needed downgradient of F10-RS234.

- See response to Specific Comment 75. Resampling of MW00-205D showed confirmation of NG at a concentration that was only 25% of the previous result (4.78 J vs 1.13 J ug/L), but still in excess of the PSV. No other zone in this well or upgradient and downgradient multizone wells 147-RS1978 and MW00-212D showed the presence of NG. The

delineation is considered complete and no further monitoring wells will be pursued.

- With the complete replacement of Chapter 5 in the Rev 1 document this text no longer exists.
- The elevated 2-NT result is indeed anomalous and is one of only two detections of 2-NT in spring groundwater. But lacking prior analytical results for comparison, no further comment can be made regarding the analytical data. This location lies within the RSA-264 unit on the south side of Huntsville Spring Branch and adjacent to the active range. Although monitored as part of the dye tracing, no dyes were detected, confirming the source is not associated with SWMUs to the north of the creek. RSA-264 holds the responsibility for groundwater. This spring should be resampled as part of the RSA-264 RFI.

**Comment 77:** **Page 5-43, Section 5.2.3.3, 1,3-Dinitrobenzene:** The extent of 1,3-Dinitrobenzene contamination in the deep zone to the east, west, and south of well MC-MW00-205Df has not been defined both laterally and vertically. This well is also associated with other contaminants above their associated PSVs (i.e., nitroglycerin and 2-Nitrotoluene). Once the nature and extent of contamination has been determined, the RFI Report should be revised accordingly.

**Response 77:** See response to Specific Comment 75.

**Comment 78:** **Page 5-44, Section 5.2.3.4, 2,6-Dinitrotoluene:** There are several concerns with this section and are bulleted below:

- An additional well should be installed to the west of the PSV exceedance in well H52-RS133 (located in the northwestern portion of RSA-052). The groundwater flow shown on Figure 3-8 indicates a westerly flow. There are no wells downgradient of the 2,6-Dinitrotoluene PSV exceedance.
- Additional wells should be installed to the north and west of the 2,6-Dinitrotoluene PSV exceedance in well F139-RS522 (located north of RSA-139). The groundwater flow shown on Figure 3-8 indicates a southwesterly flow. There are no wells downgradient of the 2,6-Dinitrotoluene PSV exceedance.
- The extent of 2,6-Dinitrotoluene contamination in the deep zone south of well F10-RS488 has not been defined to the south or vertically. This well also indicates nitroglycerin as having a concentration above its PSV (see Specific Comment No. □ above).
- The third paragraph indicates there are wells to the south of F10-RS488 that delineate 2,6-Dinitrotoluene. Please revise this section by clarifying

which wells delineate 2,6-Dinitrotoluene to the south of well F10-RS488. Please refer to the preceding bullet above.

Once the nature and extent of 2,6-Dinitrotoluene contamination has been determined, the RFI Report should be revised accordingly.

**Response 78:** See response to Specific Comment No. 75, bullet 1.

- In response to this comment, a new well was installed to the north of F139-RS522 in part to confirm the northerly hydraulic gradient and to bound the extent of 2,6-DNT. Further well F139-RS522 was resampled in January 2017 to confirm the presence of 2,6-DNT. While the new well (147-RS2848) is in fact downgradient, 2,6-DNT was not detected in either well. As a result, the delineation is deemed complete.
- See response to Specific Comment Nos 75, 76 and 78.
- The entire Chapter 5 has been replaced in the Rev 1 document. The comment focuses on RSA-010 which is responsible for the delineation and remedy of groundwater. As a consequence and with the focus on sites and plumes for which the groundwater units are responsible only, no further discussion is needed.

**Comment 79:** **Page 5-45, Section 5.2.3.6, 3-Nitrotoluene:** There are several concerns with this section and are bulleted below:

- An additional well should be installed to the west of the 3-Nitrotoluene PSV exceedance in well H52-RS133 (located in the northwestern portion of RSA-052). The groundwater flow shown on Figure 3-8 indicates a westerly flow. There are no wells downgradient of the 3-Nitrotoluene PSV exceedance.
- For the discussion of well F10-RS488 with 3-Nitrotoluene above its PSV, please refer to Specific Comment No. 78, third and fourth bullet.
- Because 3-Nitrotoluene exceeds its PSV in well 148-RS1978c and d, it appears that the nature and extent both laterally and vertically have not been defined. The last sentence in the first full paragraph on page 5-46 states, "Deep zone PSV exceedances are delineated by the existing groundwater unit data." It is unclear as to what groundwater unit data the Army is referencing. This leaves uncertainty for the reader as to what data are being interpreted. The Army should revise the RFI Report by clearly defining the parameters of the "groundwater unit data" (i.e., nature and extent based on defensible lateral and vertical extent based on well placement, groundwater flow, PSV exceedances, etc.). Please refer to General Comments No. 1-4 and revise the RFI Report accordingly.
- This section states an exceedance was detected in shallow groundwater at seven locations. The exceedance at monitoring well RS133 appears on

Figure 5-32a but is stated to be outside of the RSA-149 southwest boundary. The well is southwest of MSFC but within the RSA-052 and RSA-149 boundary. Same as in Section 5.2.3.7.

- This section states an exceedance was detected in deep groundwater at two intervals of well RS1978. This location appears on Figure 5-32b but is stated to be south of RSA-148. The well is south of MSFC but within the RSA-148 boundary.

Once the nature and extent of 3-Nitrotoluene contamination has been determined, the RFI Report should be revised accordingly.

**Response 79:** See response to Specific Comment 75, bullet 1.

- See response to Specific Comment 75, 76, and 78.
- Regarding the 3-NT detections in ports c and d of multizone well 148-RS1978, all four ports of this FLUTE well was resampled in January 2017 in part to provide a second sample event but also to confirm or refute the 3-NT (and alpha-BHC, beta-BHC results). The sampling results showed no presence (non-detect) of 3-NT in any of the monitored intervals of RS1978. Additionally, the downgradient wells MW00-205D and MW00-212D were also resampled (see previous responses) and did not detect 3-NT. The remainder of the comment involving *clearly defining the parameters of the "groundwater unit data"* is unclear.
- The text described is in fact in error. However, the entire Chapter 5 has been replaced such that this statement is no longer present and the comment moot.

**Comment 80:** **Page 5-46, Section 5.2.3.7, 2,4-Dinitrotoluene, Second Paragraph, Third Sentence:** The sentence references well location H52-RS133 as having a 2,4-Dinitrotoluene concentration in excess of its PSV. It appears that groundwater at H52-RS133 has several constituents above their respective PSVs. Please refer to Specific Comment Nos. 75, 78, and 79, and General Comments No. 1-4 and revise the RFI Report accordingly.

**Response 80:** See responses to Specific Comment Nos. 75, 78, and 79, and General Comments No. 1-4.

**Comment 81:** **Page 5-46, Section 5.2.3.8, RDX:** There are several concerns with this section and are bulleted below:

- The Department does not agree with the assumption that RDX in groundwater is delineated within RSA-147/148/149. Well H61-RS755 has an RDX concentration of 109 µg/L in the northern portion of RSA-061. The RFI Report for RSA-061 is due February 4, 2021. Apparently, wells are not scheduled to be installed in the near future for the purpose of the RSA-061 RFI Report. Given that RDX was also found in deep well

MC-MW00-205Df above its PSV, which is south of RSA-061, it appears that nature and extent have not been fully defined. However, in order to meet the nature and extent of contamination for RDX vertically, a deep well(s) should be installed near or in-between the locations of well H61-RS755 and MC-MW00-205Df for vertical delineation.

- On Page 5-47, Section 5.2.3.8, RDX, second paragraph, the third sentence states, “There are no downgradient RDX PSV exceedances within this site, and RDX in this portion of the RSA-148 groundwater unit is delineated by the existing data.” Please revise this section by clarifying and defining “existing data”, and identify which well or wells delineate the vertical and lateral extent.
- It is understood that upwelling (i.e., upward hydraulic gradients) occurs in many of the areas associated with wetland/discharge areas, including the area around well MC-MW00-205Df. It is also understood that contaminants above PSVs are many times associated with the deepest drilled wells. If upwelling is occurring as suggested in this section, please revise the document by clarifying why the deep contamination is not detected in the shallower zones and/or springs as groundwater upwells. If there is deep contamination above PSVs along with shallow wells below PSVs or non-detects in the same area, it would suggest that deeper wells should be installed to determine the depth of contamination regardless of the upward hydraulic gradients. The Army should not assume that just because deep contamination is detected in upwelling areas that the depth of contamination has been determined. Please refer to General Comments No. 2-4 and revise the RFI Report accordingly.

Once the nature and extent of RDX contamination has been determined, the RFI Report should be revised accordingly.

**Response 81:** Disagree. RSA-061 is responsible for groundwater delineation and remedy as warranted so no further investigation required on the part of the groundwater unit. Further, with the focus of the Rev 1 RFI on sites and plumes for which the groundwater unit is responsible only, no further evaluation will be provided at this time. However, the Army disagrees with the assessment that additional wells, including vertical delineation, is needed. H61-RS755 is a shallow overburden well which as noted, showed a 2013 RDX result of 109 ug/L. This result is inconsistent with previous sampling results which were non-detect for explosives (including RDX) such that resampling under the RSA-061 RFI is certainly warranted to confirm this result. Groundwater flow is to the south and this elevated result is bounded by over a dozen non-detect results (monitoring wells and DPT samples) such that the data are sufficient to claim delineation is complete. With respect to vertical extent of contamination, the results from downgradient multizone well MW00-205D showed RDX detections in 4 of the 6 bedrock intervals, three of which were estimated concentrations well below the PSV and one PSV exceedance (4.68 J) in the deepest sample interval at the Chattanooga Shale. This was the only explosives sample from this well. To confirm the results and in response to

ADEM comments, all six ports of MW00-205D were resampled in January 2017. The results showed were non-detect in all zones of MW00-205D. Therefore no further delineation is required.

- With the complete replacement of Chapter 5 in the Rev 1 RFI the text cited no longer exists.
- See responses to General Comments No. 2-4.

**Comment 82:** Page 5-47, Section 5.2.3.9, 2-Amino-4,6-Dinitrotoluene and 4-Amino-2,6-Dinitrotoluene: There are several concerns with this section and are bulleted below:

- The Department does not agree with the assumption that 2-Amino-4,6-Dinitrotoluene (2-ADNT) in groundwater is delineated within RSA-147/148/149. Well H61-RS755 has a 2-ADNT concentration of 10.4 J µg/L in the northern portion of RSA-061. The RFI Report for RSA-061 is due February 4, 2021. Apparently, wells are not scheduled to be installed in the near future for the purpose of the RSA-061 RFI Report. Given that 2-ADNT was also found in deep well MC-MW00-205Df above its PSV, which is south of RSA-061, it appears that nature and extent have not been fully defined. However, in order to meet the nature and extent of contamination for 2-ADNT vertically, a deep well(s) should be installed near or in-between the locations of well H61-RS755 and MC-MW00-205Df for vertical delineation.
- The Department does not agree with the assumption that 4-Amino-2,6-Dinitrotoluene (2-ADNT) in groundwater is delineated within RSA-147/148/149. Well H61-RS755 has a 2-ADNT concentration above its PSV in the northern portion of RSA-061. The RFI Report for RSA-061 is due February 4, 2021. Apparently, wells are not scheduled to be installed in the near future for the purpose of the RSA-061 RFI Report.
- Because these contaminants (i.e., 2-ADNT and 4-ADNT) are associated with other contaminants in the same wells, please refer to Specific Comment No. 82, and revise the RFI Report accordingly.
- This section states a January 2012 exceedance was detected in deep groundwater at one interval of well MW00-205D. This location appears on Figure 5-36b but is stated to be south of RSA-148. The well is south of MSFC but within the RSA-148 boundary. Other constituents exceeded a PSV at this location in 2012, comment on the detection at this location.

Once the nature and extent of RDX contamination has been determined, the RFI Report should be revised accordingly.

**Response 82:** Disagree. See response to Specific Comment No 81, bullet 1. The distribution and extent of 2-ADNT is similarly bounded in the shallow groundwater. 2-ADNT was detected in MW00-205Df (the deepest interval at

a concentration of 4.68 J ug/L in 2012. Resampling this well in January 2017 confirmed the presence of 2-ADNT but at concentration below the PSV (2.19 ug/L). No additional vertical delineation is needed to chase explosives at RSA-061.

- Apart from MW00-205D discussed in the first bulleted comment, there are no other exceedances of 2-ADNT within or immediately south of H61-RS755. In fact, the 5.51 ug/L exceedance is bounded by over a dozen non-detect results from monitoring wells and DPT samples further downgradient along the flowpath.
- The explosive compound (2-NT, 3-NT, NG, 1,3-DNBZ, RDX, 2-ADNT, 4-ADNT) results in MW00-205D are anomalous. All six ports of this well were resampled in January 2017 to confirm the results. With the exception of NG (see response to Specific Comment 76) there were no exceedances. Per prior responses, 2-NT, 3-NT, 1,3-DNBZ, and RDX were non-detect in the January 2017 samples from all intervals.

**Comment 83:** **Page 5-49, Section 5.2.3.11, Summary, Last two Bullets:** The Department does not agree that full delineation based on the scale of the groundwater unit has been determined for the eleven explosive compounds that exceeds their respective PSVs in the shallow and deep groundwater. Please refer to Specific Comment Nos. 75 through 82 and revise the RFI Report accordingly.

**Response 83:** See responses to Specific Comment Nos. 75 through 82. In accordance with ADEMs focus on exposure unit scale delineation, the Rev 1 RFI has been completely revised to focus on the plumes and areas for which the groundwater unit has responsibility only.

**Comment 84:** **Page 5-49, Section 5.2.4.1, beta-BHC:** There are several concerns with this section and are bulleted below:

- The RFI Report for RSA-252 has not been completed to date. A deep well has recently been installed in the parking lot to the west of Building 5681 and lab results have not been evaluated for the recently collected deep groundwater sample. This well was installed to determine the depth of contamination at RSA-252. Therefore, it is premature to determine the nature and extent of beta-BHC contamination in the area of RSA-252. Pending the analytical results of the deep groundwater sample, the Department does not agree at this time that the depth of contamination has been determined for beta-BHC.
- The shallow plume to the west of RSA-252 does not appear to be defined. Figure 3-8 indicates that groundwater flow is to the west. The Army should install wells to the west of the beta-BHC plume indicated on Figure 5-37a to determine the lateral extent of contamination.
- Because beta-BHC exceeds its PSV in both shallow and deep groundwater at well location 148-RS1978b, c, and d, it appears that the nature and

extent both laterally and vertically have not been defined. The last sentence in the top paragraph on page 5-53 states, "Consequently, beta-BHC in groundwater is delineated from a groundwater unit-scale perspective." It is unclear as to what groundwater unit data the Army is referencing. This leaves uncertainty for the reader as to what data are being interpreted. Please also refer to Specific Comment No. 79 (i.e., third bullet) and General Comment No. 2 and revise the RFI Report accordingly.

**Response 84:** As noted in the comment, a deep well was installed and sampled to complete the delineation of the vertical extent at this unit. The Rev 2 RSA-252 RFI report which included the results for this well has since been approved by ADEM on 11/16/16 such that the delineation of contamination is complete at this unit. RSA-252 maintains the responsibility for delineation and remedy of groundwater such that no further investigation is required on the part of the groundwater unit.

- See response above. The lateral extent of contamination related to RSA-252 was achieved via the approved Rev 2 RFI report.
- See response to Specific Comment No. 79 (i.e., third bullet) and General Comment No. 2. Well 148-RS1978 has only been sampled once at the time the Rev 0 RFI report was submitted. To address ADEM comment and to provide a second round of sampling all four ports of the 147-RS1978 FLUTE well were resampled in January 2017. The results of this sampling show that neither alpha-BHC or beta-BHC are present in any interval of multizone well 148-RS1978; all samples were ND for these compounds.

**Comment 85:** **Page 5-53, Section 5.2.4.2, alpha-BHC:** Because there are similarities in the locations of the beta-BHC and alpha-BHC contamination, please refer to Specific Comment No. 84 and revise the RFI Report accordingly.

In addition, it appears that alpha-BHC is above its PSV at well 147-RS2249S. It also appears from Figure 3-8 that groundwater flow is to the south and east depending on the seasonal flow directions. It appears that alpha-BHC has not been defined to the east and additional wells should be installed to define the nature and extent of contamination.

Once the nature and extent of alpha-BHC contamination has been determined, the RFI Report should be revised accordingly.

**Response 85:** See response to Specific Comment No. 84. The pesticide exceedances in 147-RS1978 were addressed via resampling in January 2017. Well 147-RS2249S lies within RSA-117, which holds the responsibility for delineation and remedy of groundwater. No further investigation is required on the part of RSA-147.



**Comment 86:** **Page 5-55, Section 5.2.4.3, Aldrin:** The Army should determine the nature and extent of aldrin to the west of RSA-252 based on the same rationale as described in Specific Comment Nos. 84 and 85 for beta-BHC and alpha-BHC respectively. The report should be revised accordingly.

**Response 86:** See response to Specific Comment Nos. 84 and 85.

**Comment 87:** **Page 5-55, Section 5.2.4.3, Aldrin:** This pesticide was detected as plumes in several areas, one of which was RSA-226. Sources are indicated to be difficult to determine as this site is listed as an open storage area. However, this area is adjacent to and associated with Redstone Arsenal tenants that use the area for on-going land management operations, such as grounds keeping activities. These operations, in part, utilize pesticides for property management. Please Address.

**Response 87:** The point is noted, however, it is not the intent of the groundwater RFI to identify sources. This was addressed in the now completed RSA-226 surface media site RFI (RFI approved 9/30/15). In that RFI, it was pointed out that Aldrin (and Dieldrin) is present in near equal concentrations in upgradient and onsite wells and despite low frequency detection in site subsurface soils, does not appear sourced by RSA-226. In the revised RFI, the area including RSA-226 is addressed as a plume area, and all available groundwater data has been used to map plumes which ideally point towards a number of potential contributing sources.

**Comment 88:** **Page 5-55, Section 5.2.4.4, Dieldrin:** It appears from Figure 5-40a that well F118-RS875 has a concentration of dieldrin above its PSV. The groundwater flow appears to be to the south (see Figure 3-8) or to the east depending on the time of year. The Army should install additional wells to the east to define the lateral extent of contamination.

In addition, it appears that dieldrin is above its PSV at well 147-RS2249S. It also appears from Figure 3-8 that groundwater flow is to the south and east depending on the seasonal flow directions. It appears that dieldrin has not been defined to the east and additional wells should be installed to define the nature and extent of contamination.

Once the nature and extent of dieldrin contamination has been determined, the RFI Report should be revised accordingly.

**Response 88:** The comment pertains to RSA-117 for which the groundwater delineation and remedy is the responsibility of the surface media site (RSA-117). Any further investigations to delineate the extent of dieldrin will be addressed via the surface media site RFI.

**Comment 89:** **Page 5-56, Section 5.2.4.5, 4,4'-DDD:** There are several concerns with this section and are bulleted below:

- The RFI Report for RSA-252 has not been completed to date. A deep well has recently been installed in the parking lot to the west of Building 5681 and lab results have not been evaluated for the recently collected deep groundwater sample. This well was installed to determine the depth of contamination at RSA-252. Therefore, it is premature to determine the nature and extent of 4,4'-DDD contamination in the area of RSA-252. Pending the analytical results of the deep groundwater sample, the Department does not agree at this time that the depth of contamination has been determined for 4,4'-DDD. If the results show 4,4'-DDD contamination above PSVs in the deep well, the Army should continue to determine the vertical extent of contamination. Once the results are completed, please revise the RFI Report accordingly.
- The shallow plume to the west of RSA-252 does not appear to be defined. Figure 3-8 indicates that groundwater flow is to the west. The Army should install wells to the west of the 4,4'-DDD plume indicated on Figure 5-41a to determine the lateral extent of contamination.
- It appears that 4,4'-DDD is above its PSV at well 147-RS2249S. It also appears from Figure 3-8 that groundwater flow is to the south and east depending on the seasonal flow directions. It appears that 4,4'-DDD has not been defined to the east and additional wells should be installed to define the nature and extent of contamination.
- Because 4,4'-DDD has been associated with the CBZ dense non-aqueous phase liquid (DNAPL), please refer to Specific Comment Nos. 38 through 40 and revise the RFI Report Accordingly
- It appears that the nature and extent of 4,4'-DDD contamination in groundwater has not been defined to the south and west of well 148-RS1980 in the vicinity and southwest of RSA-060 (see Figure 5-43a). Figure 3-8 indicates a southerly/southwesterly groundwater flow. The Army should install wells to the south and west of well 148-RS1980 to determine the lateral and vertical extent of 4,4'-DDD.

Once the nature and extent of 4,4'-DDD contamination has been determined, the RFI Report should be revised accordingly.

**Response 89:**

The results for bedrock well 252-RS2761 were non-detect for 4,4'-DDD. Further, the RSA-252 RFI has since been approved by ADEM via concurrence letter dated 11/16/16 such that delineation of nature and extent for that unit is complete.

- See response above. The delineation of contamination associated with RSA-252 is complete.
- The comment refers to RSA-117, for which the surface media site is responsible for groundwater. Any further investigations will need to be completed as part of the RSA-117 RFI.

- See responses to Specific Comment Nos. 38 through 40.
- Wells 148-RS1980 and 148-RS1981 are two shallow overburden wells that were recently installed along the elevated roadway through the wetlands to the west of RSA-060. RS1980 encountered bedrock at 17 feet and is completed from 7-17 ft bgs. RS1981 encountered bedrock at 50 ft and is completed from 40-50' bgs.

Both wells have been sampled twice, in January and December 2012. DDD was detected above the PSV in RS1980 in both events while DDE and DDT were only present in one event each (inconsistent results). Higher concentrations of DDD (2.6 ug/L) were detected in RS1981, the well further to the west.

	PSV	148-RS1980		148-RS1981	
		1/13/2012	12/20/2012	1/13/2012	12/20/2012
'4,4-DDD	0.03	<u>0.24</u>	<u>0.08</u>	<u>2.1</u>	<u>2.6</u>
'4,4-DDT	0.23	<u>0.31</u>	ND	0.0065	ND
'4,4-DDE	0.23	0.04	0.024	0.15	0.15
Aldrin	0.0046	<u>0.04</u>	ND	ND	ND
alpha-BHC	0.0071	<u>0.0875</u>	ND	ND	ND
TCE	5	<u>41</u>	ND	0.38	0.69
1,2-DCA	5	ND	0.35	ND	<u>9</u>
Vinyl Chloride	2	1.61	ND	<u>8.14</u>	<u>5.5</u>

Both of these wells are within the DDT abatement area (RSA-101) and quite removed from RSA-060 as a source. It is more likely these data represent residual DDT contamination from the wetland itself rather than sourcing from RSA-060.

**Comment 90:** Page 5-59, Section 5.2.4.6, 4,4'-DDT: There are several concerns with this section and are bulleted below.

- The RFI Report for RSA-252 has not been completed to date. A deep well has recently been installed in the parking lot to the west of Building 5681 and lab results have not been evaluated for the recently collected deep groundwater sample. This well was installed to determine the depth of contamination at RSA-252. Therefore, it is premature to determine that the nature and extent of 4,4'-DDT contamination in the area of RSA-252 has been achieved. Pending the analytical results of the deep groundwater sample, the Department does not agree at this time that the depth of contamination has been determined for 4,4'-DDT. If the results show 4,4'-DDT contamination above PSVs in the deep well, the Army should continue to determine the vertical extent of contamination. Once the results are completed, please revise the RFI Report accordingly.

- The shallow plume to the west and north of RSA-252 does not appear to be defined. Figure 3-8 indicates that groundwater flow is to the west. The Army should install wells to the west of the 4,4'-DDT plumes indicated on Figure 5-42a to determine the lateral extent of contamination.
- It appears that 4,4'-DDT is above its PSV at well 147-RS2248S. It also appears from Figure 3-8 that groundwater flow is to the south and east depending on the seasonal flow directions. It appears that 4,4'-DDT has not been defined to the east and south and additional wells should be installed to define the nature and extent of contamination.
- Because 4,4'-DDT has been associated with the CBZ DNAPL, please refer to Specific Comment Nos. 38 through 40 and revise the RFI Report Accordingly.

Once the nature and extent of 4,4'-DDT contamination has been determined, the RFI Report should be revised accordingly.

**Response 90:** See responses to specific bulleted comments below:

- See response to Specific Comment No 89, bullet 1.
- See response to Specific Comment No 89, bullet 2.
- See response to Specific Comment No 89, bullet 3.
- See responses to Specific Comment Nos. 38 through 40 .

**Comment 91:** **Page 5-60, Section 5.2.4.7, 4,4'-DDE:** There are several concerns with this section and are bulleted below:

- It appears that the nature and extent of contamination in groundwater has not been defined to the south and west of well 148-RS1980 in the vicinity and southwest of RSA-060 (see Figure 5-43a). Figure 3-8 indicates a southerly/southwesterly groundwater flow. The Army should install wells to the south and west of well 148-RS1980 to determine the lateral and vertical extent of 4,4'-DDE.
- It appears that 4,4'-DDE is above its PSV at well 147-RS2248S. It also appears from Figure 3-8 that groundwater flow is to the south and east depending on the seasonal flow directions. It appears that 4,4'-DDE has not been defined to the east and south and additional wells should be installed to define the nature and extent of contamination.
- Because 4,4'-DDE has been associated with the CBZ DNAPL, please refer to Specific Comment Nos. 38 through 40 and revise the RFI Report Accordingly.
- On Page 6-61, section 5.2.4.7, 4,4'-DDE, second full paragraph, the sixth sentence states, "This is supported by well 148-RS1981, located slightly

downgradient of 148-RS1980, which contained 4,4'-DDE at 0.15 µg/L, slightly below the PSV, suggesting further attenuation farther away from RSA-060." According to Figure 3-8, the flow is to the south and south west. The Department does not agree with the Army's assumption that well location 148-RS1981 is "slightly downgradient" of well location 148-RS1980. Please refer to Bullet No. 1 above and revise the RFI Report accordingly.

Once the nature and extent of 4,4'-DDE contamination has been determined, the RFI Report should be revised accordingly.

**Response 91:** See responses to specific bulleted comments below:

- See response to Specific Comment 89, bullet 5.
- See response to Specific Comment No 89, bullet 3.
- See responses to Specific Comment Nos. 38 through 40.
- See response to Specific Comment 89, bullet 5.

**Comment 92:** **Page 5-62, Section 5.2.4.8, Heptachlor Epoxide:** The RFI Report for RSA-252 has not been completed to date. A deep well has recently been installed in the parking lot to the west of Building 5681 and lab results have not been evaluated for the recently collected deep groundwater sample. This well was installed to determine the depth of contamination at RSA-252. Therefore, it is premature to determine that the nature and extent of heptachlor epoxide contamination in the area of RSA-252 has been achieved. Pending the analytical results of the deep groundwater sample, the Department does not agree at this time that the depth of contamination has been determined for heptachlor epoxide. If the results show heptachlor epoxide contamination above PSVs in the deep well, the Army should continue to determine the vertical extent of contamination. Once the results are completed, please revise the RFI Report accordingly.

**Response 92:** RSA-252 is responsible for the delineation and remedy of groundwater at this site. As noted in the comment a deep well (252-RS2761) was installed as part of the RFI for RSA-252. The nature and extent of contamination associated with that site has been completed and the RFI approved via ADEM concurrence letter dated 11/16/16.

**Comment 93:** **Page 5-65, Section 5.2.4.10, Toxaphene:** The RFI Report for RSA-252 has not been completed to date. A deep well has recently been installed in the parking lot to the west of Building 5681 and lab results have not been evaluated for the recently collected deep groundwater sample. This well was installed to determine the depth of contamination at RSA-252. Therefore, it is premature to determine that the nature and extent of toxaphene contamination in the area of RSA-252 has been achieved. Pending the analytical results of the deep groundwater sample, the Department does not agree at this time that

the depth of contamination has been determined for toxaphene. If the results show toxaphene contamination above PSVs in the deep well, the Army should continue to determine the vertical extent of contamination. Once the results are completed, please revise the RFI Report accordingly.

**Response 93:** See response to Specific Comment No. 92.

**Comment 94:** **Page 5-66, Section 5.2.4.10, Endrin Aldehyde:** The RFI Report for RSA-252 has not been completed to date. A deep well has recently been installed in the parking lot to the west of Building 5681 and lab results have not been evaluated for the recently collected deep groundwater sample. This well was installed to determine the depth of contamination at RSA-252. Therefore, it is premature to determine that the nature and extent of endrin aldehyde contamination in the area of RSA-252 has been achieved. Pending the analytical results of the deep groundwater sample, the Department does not agree at this time that the depth of contamination has been determined for endrin aldehyde. If the results show endrin aldehyde contamination above PSVs in the deep well, the Army should continue to determine the vertical extent of contamination. Once the results are completed, please revise the RFI Report accordingly.

**Response 94:** See response to Specific Comment No. 92.

**Comment 95:** **Page 5-67, Section 5.2.4.11, Summary, Last Bullet:** The Department does not agree that full delineation base on the scale of the groundwater unit has been determined for the pesticide compounds that exceeds their respective PSVs in the shallow and deep groundwater. Please refer to Specific Comment Nos. 84 through 94 and revise the RFI Report accordingly.

**Response 95:** See responses to Specific Comment Nos. 84 through 94.

**Comment 96:** **Page 5-69, Section 5.2.5.2, PCBs Detected at Low Frequencies of Exceedances, Third Paragraph, Last Sentence:** Please revise the sentence by changing "Aroclor 1242" to "Aroclor 1016".

**Response 96:** The comment is noted. However, the entire Chapter has been replaced such that the comment is now moot.

**Comment 97:** **Page 5-69, Section 5.2.5.2, PCBs Detected at Low Frequencies of Exceedances, Fourth Paragraph, First and Fourth Sentences:** Please revise the first sentence by changing "Figure E-18a" to "Figure E-17a" and change the fourth sentence by changing "Figure E-18b" to "Figure E-17b".

**Response 97:** The comment is noted. However, the entire Chapter has been replaced such that the comment is now moot.

**Comment 98:** **Page 5-70, Section 5.2.5.2, PCBs Detected at Low Frequencies of Exceedances, Fourth Paragraph, Fifth and Sixth Sentences:** Please revise the fifth sentence by changing “Figure E-23a” to “Figure E-22a” and change the fourth sentence by changing “Figure E-23b” to “Figure E-22b”.

**Response 98:** The comment is noted. However, the entire Chapter has been replaced such that the comment is now moot.

**Comment 99:** **Page 5-70, Section 5.2.6, Metals in Groundwater and Surface Water:** This section does not expand its discussion of “anomalous” metal detects above PSVs as related to nature and extent. For example, in well location F54-RS304 (i.e., arsenic concentration is 30 µg/L) shown on Figure 5-48a, the extent of arsenic contamination has not been defined to the west of RSA-054 or vertically. Anomalous metals that have not been bounded by other wells both vertically and laterally, should be further investigated to determine the nature and extent. Please determine which anomalous metals should be further investigated for nature and extent and follow up with an investigation to delineate the nature and extent and revise the RFI Report accordingly.

The well locations should be labeled on Figures 5-48a and 5-48b for easy reference. It is sometimes difficult to navigate which well the Army is referencing on the figures throughout the report and in addition to cross-referencing the analytical results along with the direction of flow during the time the samples were collected. Figure 3-8 does not always indicate the actual flow directions based on when the samples were collected. For example, RSA-252 actually has four different directions of flow depending on the time of year. Please revise the RFI Report by including the well references on Figures 5-6a through 5-48b. Please also add the proper direction of groundwater flow during critical sampling events as appropriate.

**Response 99:** The entire Chapter has been replaced such that the comment is now moot.

**Comment 100:** **Page 5-71, Section 5.2.6, Metals in Groundwater and Surface Water, Second Full Paragraph:** The paragraph states, “Cobalt, thallium, and vanadium are not within the CSM of this site. Therefore, these elements are not included in this evaluation.” The Department does not agree that these elements should be eliminated based on a broad assumption that they were never used in a process or were never present at Redstone Arsenal. If the concentrations of these elements are above their respective PSVs, they must be evaluated similarly to other metals. Please note, however, that cobalt molybdate is used to convert crude oil to other petroleum products. In addition, cobalt and vanadium can be found in crude oil. The Department understands that the National Aeronautics and Space Administration (NASA) Marshal Space Flight Center (MSFC) is evaluating these three elements as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process. Please provide other lines of evidence in the revised RFI Report to show these elements are not constituents of RSA-147/148/149 where crude oil was used if appropriate.

- Response 100:** In the revised report, cobalt, thallium and vanadium will be included in the evaluation of metals. Regarding MSFC, NASA is responsible for all groundwater within MSFC, including the three metals should they deem them to be a component of their CSM.
- Comment 101:** **Page 5-75, Section 5.3.1, Interior Plume Areas, First Paragraph, Third Sentence:** The sentence states, "The presentation of the nature and extent of each individual contaminant in groundwater showed the distribution of each compound, with areas of PSV exceedance clearly delineated on figures." The Department does not agree that all the plumes have been clearly delineated. Please refer to General Comments No. 1-4 and all Specific Comments noted above and revise the RFI Report accordingly.
- Response 101:** See responses to General Comments No. 1-4 and all Specific Comments noted above.
- Comment 102:** **Page 5-75, Section 5.3.1, Interior Plume Areas, Third Paragraph, Third Sentence:** The sentence states, "Nonetheless, the plume areas shown on Figure 5-49 describe the extent of all COCs present at concentration exceeding the PSVs." The Department does not agree that all the plumes have been clearly delineated. Please refer to General Comments No. 1-4 and all Specific Comments noted above and revise the RFI Report accordingly.
- Response 102:** See responses to General Comments No. 1-4 and all Specific Comments noted above
- Comment 103:** **Page 5-76, Section 5.3.1, Interior Plume Areas, First Full Paragraph, Last Two Sentences:** The last two sentences state, "Although the maximum depth of DNAPL occurrence has not been determined, the available data show a) the DNAPL is present in an interval below the depth of active groundwater circulation, and b) elevated CBZ was not observed in downgradient wells. Consequently, it appears the DNAPL and associated dissolved-phase groundwater contamination in the deep flow component is constrained." The Department does not agree that the depth of DNAPL and dissolved contamination has been determined. Please refer to General Comments No. 1-4 and all appropriate Specific Comments related to CBZ and other dissolved constituents at depth and revise the RFI Report accordingly.
- Response 103:** See responses to General Comments No. 1-4 and all relevant Specific Comments noted above. This comment appears to be specifically targeting RSA-117 which holds the responsibility for groundwater. Any further investigations will need to be completed under the RFI for that unit.
- Comment 104:** **Page 5-79, Section 5.3.2, Downgradient Extent:** Nature and extent of exceedances in springs and surface water are indicated in the broad discharge zone. Integrated Operable Units (IOUs) are beyond the scope of this RFI, this statement is reiterated in a bullet on Page 5-86. The revised report should state detections will be further assessed during the IOU investigation.



- Response 104:** Chapter 1 of the Rev 1 RFI has been revised to specifically distinguish responsibility for delineation and remedy of groundwater, with the groundwater unit RFI focusing only on those areas for which it has responsibility.
- Comment 105:** **Page 5-80, Section 5.3.3, Key Findings, VOCs, Last Bullet, First Sentence:** The sentence states, "All VOC contaminants are delineated in the shallow and deep flow zones at a scale of the groundwater unit by monitoring locations where concentrations are below the PSV or are not detected." The Department does not agree that full delineation based on the scale of the groundwater unit has been determined for the VOC compounds that exceeds their respective PSVs in the shallow and deep groundwater. Please refer to Specific Comment Nos. 32 through 66 and revise the RFI Report accordingly.
- Response 105:** See responses to Specific Comment Nos. 32 through 66.
- Comment 106:** **Page 5-80, Section 5.3.3 Key Findings, VOCs fifth bullet:** The report states VOCs emerge in the groundwater discharge zone to the south and west of RSA-147/148/149. Clarify the discharge zone is primarily within the RSA-147/148/149 boundary, not south and west of the groundwater units.
- Response 106:** Agree. However, the entire chapter has been replaced such that the comment is now moot.
- Comment 107:** **Page 5-80, Section 5.3.3 Key Findings, VOCs last bullet:** The report states contaminant migration is being monitored in the downgradient groundwater discharge zone. This comment is stated in the VOC, SVOC, and Explosive Compounds subsections of the Key Findings. NASA/MSFC conducts semiannual groundwater monitoring which includes some multi-interval wells and springs in the discharge zone. Clarify what monitoring is being conducted by the Army.
- Response 107:** Monitoring is being conducted by NASA-MSFC 11 springs and wells within the discharge zone within the NASA OU-3 boundary. Monitoring is ongoing in wells within the discharge zone associated with the RSA-053 (MWs and one spring) and RSA-060 CMIPs, at select locations in RSA-010 as part of the Solid Waste Permit.
- Comment 108:** **Page 5-81, Section 5.3.3, Key Findings, SVOCs, Last Bullet:** The last bullet states, "All SVOCs are delineated at the scale of the groundwater unit and are being monitored in the downgradient groundwater discharge zone associated with Huntsville Spring Branch and Indian Creek." The Department does not agree that all SVOCs have been delineated. Please refer to Specific Comments Nos. 0-0 and revise the RFI Report accordingly.
- Response 108:** See response to Specific Comments Nos. 0-0
- Comment 109:** **Page 5-81, Section 5.3.3, Key Findings, Explosive Compounds, First and Fourth Bullet:** A minor, one-well plume is indicated at RSA-061. Section

5.2.3.8 RDX and Figures 5-34 do not depict a mappable plume of RDX. Please revise this section by defining a one-well plume of RDX.

**Response 109:** Comment noted.

**Comment 110:** **Page 5-82, Section 5.3.3, Key Findings, Explosive Compounds, Last Bullet:** The last bullet states, “The remaining PSV exceedances, including most of the deep zone exceedances are generally of low concentration, sporadic in nature, and delineated at the scale of the groundwater unit.” The Department does not agree that full delineation based on the scale of the groundwater unit has been determined for the eleven explosive compounds that exceeds their respective PSVs in the shallow and deep groundwater. Please refer to Specific Comment Nos. 75 through 83 and revise the RFI Report accordingly.

**Response 110:** See response to Specific Comment Nos. 75 through 83.

**Comment 111:** **Page 5-82, Section 5.3.3, Key Findings, Pesticides, Last Bullet:** The last bullet states, “At the groundwater unit scale, pesticides exceedances in groundwater are delineated by locations where they are found to be below PSVs or were not detected.” The Department does not agree that full delineation based on the scale of the groundwater unit has been determined for the pesticide compounds that exceeds their respective PSVs in the shallow and deep groundwater. Please refer to Specific Comment Nos. 84 through 95 and revise the RFI Report accordingly.

**Response 111:** See response to Specific Comment Nos. 84 through 95.

**Comment 112:** **Page 5-83, Section 5.3.3, Key Findings, Metals, Last Bullet:** The last bullet states, “All locations of anomalous metals concentrations are delineated by locations where metals concentrations are considered to be natural constituents of groundwater and surface water.” Please refer to Specific Comment Nos. 99 through 100 and revise the RFI Report accordingly.

**Response 112:** See response to Specific Comment Nos. 99 through 100.

**Comment 113:** **Page 5-84 and 5-85, Key Findings, Interior Plume Areas, Bullet Nos. 4 and 6:** The fourth bullet states, “The extent of the CBZ DNAPL at RSA-117 is not fully delineated, but it appears to be deep, sequestered, and immobile and thus is considered bounded. CBZ was not detected in downgradient wells and or springs within or south/downgradient of RSA-147/148/149.” The sixth bullet states, “The interior plumes are well defined in the lateral and vertical sense by wells where results were either nondetect or where contaminants were detected at concentrations below PSVs. DNAPL and associated dissolved phase groundwater contamination in the deep flow component is at least constrained.” The Department does not agree that full delineation based on the scale of the groundwater unit has been determined for the DNAPL compounds and contaminants that exceeds their respective PSVs in the

shallow and deep groundwater. Please refer to General Comment No. 3, Specific Comment Nos. 38-40, and Specific Comment Nos. 101-103.

**Response 113:** See response to General Comment No. 3, Specific Comment Nos. 38-40, and Specific Comment Nos. 101-103.

**Comment 114:** **Page 5-86, Key Findings, Downgradient Extent, Last Bullet:** The last bullet states, “The nature of groundwater contamination within RSA-147/148/149 is well documented and the extent of plumes considered delineated at the scale of the groundwater unit.” The Department does not agree that full delineation based on the scale of the groundwater unit has been determined for the contaminants that exceed their respective PSVs in the shallow and deep groundwater. Please refer to General Comments No. 2-4, Specific Comment Nos. 38-40, Specific Comment Nos. 101-103, and Specific Comment No. 113 and revise the RFI Report accordingly.

**Response 114:** See responses to General Comments No. 2-4, Specific Comment Nos. 38-40, Specific Comment Nos. 101-103, and Specific Comment No. 113. The key phrase in this comment is “full delineation”. This concept is not achievable within the complex hydrogeologic framework of RSA. There will always be some uncertainty and it is through the groundwater unit perspective that the overall impacts of the interior plumes and sources can be appreciated. The ADEM focus on the ‘exposure unit scale’, including the specific perceived gaps in delineation advanced in the comments, amounts to nothing more than minor refinement of interior plume extent. The Army contends that delineation is sufficient to develop and pursue remedial measures, where warranted. In the Rev 1 RFI, the focus has been shifted to those plume source areas for which the groundwater unit has responsibility.

**Comment 115:** **Page 6-4, Section 6.0, Contaminant Fate and Transport, Comingled Plumes:** The comingled plumes are stated to be shown on Figure 5-49 and Table 5-3. Please revise this to Table 5-4, Summary of Army COC Plumes.

**Response 115:** Comment noted, but since the entire chapter 5 has been replaced the comment is now moot.

**Comment 116:** **Table 1-1:** This table provides information for the SWMUs included in the 147,148, and 149 groundwater unit boundary. It appears that multiple SWMUs are still under investigation, and additional field work may be necessary prior to Departmental approval of these RFIs. Therefore, because this investigation aggregated data from the previous completed and ongoing surface media investigations additional information might be necessary at certain SWMUs which have not completed the investigation phase.

**Response 116:** There will always be additional data available. However, with the Rev 1 RFI submission, Table 1-1 has been revised to clearly distinguish surface media sites that are responsible for groundwater and those that are the responsibility of the groundwater unit. The Rev 1 RFI focuses on the latter, of which all of the surface media site investigations have been completed (in some cases the

fieldwork has been completed and available for use but the report has not yet been submitted to ADEM as of this writing). All available data (including sites responsible for groundwater) have been incorporated into the Rev 1 document.

**Comment 117:** **Table 1-1:** There are several edits that should be made with this table and are bulleted below:

- According to this table it appears that MSFC-002/087 has a status of both “No Further Action (At This Time)” and “Corrective Measures Required”. Please revise the table by clarifying if both status actions should apply at the same time.
- Please add “RSA-147” along with “RSA-148” to the Groundwater Unit that RSA-114 is associated with on page 2 of 4 of the table.
- Please add “RSA-148” along with “RSA-149” to the Groundwater Unit that RSA-141 is associated with on page 3 of 4 of the table.
- Please change “RSA-148” to “RSA-147” on the Groundwater Unit that RSA-238 is associated with on page 3 of 4 of the table.

**Response 117:** Given the time between submission of the Rev 0 document, receipt of ADEM comments, and submission of the Rev 1 RFI there have been many changes to Table 1-1 in addition to those listed above. Table 1-1 has been completely updated to reflect the current conditions as of the submission date of the Rev 1 RFI. Additionally, Table 1-1 has been significantly improved to more clearly distinguish responsibility for groundwater between the surface media sites and the groundwater units.

- MSFC-002/087 is listed in Table VI.3 of the Permit (Mod 10, February 2017) as requiring no further action. The table has been corrected accordingly.
- Table corrected.
- Table corrected.
- Similar to the other examples cited in the comment, RSA-238 straddles the RSA-147/148 boundary, and not solely RSA-147 as suggested.

**Comment 118:** **Table 2-1:** There are several edits that should be made with this table and are bulleted below:

- The “Injection Elevation” column should specify the units. Please revise the column by adding units.
- Some of the “Elevations” appear to be “depth below ground surface” (BGS) and do not represent an elevation. Please revise the table by establishing all injection elevations based on established datum points

[i.e., above mean sea level (1988 North American Vertical Datum, NAVD 88)].

- In the “Post-Injection Flush” column, please clarify what the “-“ negative sign represents.

**Response 118:** See responses to specific bulleted comments below:

- Units added per comment
- All entries presented as elevations per comment
- That is not a negative sign but is a tilde (~), commonly used to express an approximate value.

**Comment 119:** **Table 3-1:** Please revise this table by clarifying the formation at Location Code MC-MW00-403.

**Response 119:** All blank formation fields have been filled, where possible.

**Comment 120:** **Table 4-2, Page 7 of 7:** The explanation states, “Cobalt, thallium, and vanadium detections are not facility related, as determined by the RSA Risk Managers in the RSA Tier 1 Team Agreement Matrix dated May 4, 2009. Agreement #40 (Redstone Tier 1 Team, 2009).” Please refer to Specific Comment No. 100 and revise this explanation as appropriate.

**Response 120:** See response to Specific Comment No. 100.

**Comment 121:** **Table 4-3, Page 8 of 8:** The explanation states, “Cobalt, thallium, and vanadium detections are not facility related, as determined by the RSA Risk Managers in the RSA Tier 1 Team Agreement Matrix dated May 4, 2009. Agreement #40 (Redstone Tier 1 Team, 2009).” Please refer to Specific Comment No. 100 and revise this explanation as appropriate.

**Response 121:** See response to Specific Comment Nos. 100 and 120.

**Comment 122:** **Table 5-1:** This table shows locations which exceed the solubility criteria indicating the potential for DNAPL presence. The method that this data is illustrated (historical and current) might lead to confusion of readers surmising that certain “historic” DNAPL indications are no longer present. This, however is not the case as multiple of the historic samples which indicate DNAPL presence have not been resampled in the current time frame. This table should be revised to better illustrate whether or not DNAPL concentrations are still believed to be present.

**Response 122:** To avoid further confusion, the table has been revised in the Rev 1 RFI to focus only on the most recent sampling results (i.e., current conditions), consistent with the remainder of the evaluation.

- Comment 123:** **Figure 5-3, Cross-section B-B’:** Monitoring wells RS1893 and RS1982 located in the vicinity of RSA-249 are labeled green indicating constituents below PSV. However, corresponding analytical data in the table indicates exceedances of TCE and TeCA in groundwater. Please clarify the figure labeling.
- Response 123:** Figure 5-3, as well as 5-4 will no longer be used in the Rev 1 document. Instead the focus will shift from the groundwater unit scale, where such sections are applicable, to the “exposure unit” scale. New cross sections will be included in presentation of the nature and extent of contamination associated with each of the plumes for which the groundwater unit has responsibility, as needed.
- Comment 124:** **Table 5-4:** This table apparently does not include information from Figure 5-48a and the first CD (RSA\_147-148-149\_Data\_Usable) showing a mercury PSV exceedance from well F54-RS036A and arsenic PSV exceedance from well F54-RS304. For “Army Plume Area P01” please revise the table by adding to the “COCs Exceeding PSV” column metals (i.e., mercury and arsenic). Please check the table for other similar edits.
- Response 124:** The exceedances cited in the comment reflect results from 2012. One of these wells (RS036A) had been sampled 5 times for Mercury(3 NDs results. The well was closed in April 2012 such that the well cannot be resampled to confirm the detection. The well was replaced by well 147-RS2504 and sampled in 2014. Mercury was not detected. Well RS304 was sampled twice in 2012 and the first sample showed arsenic at 1.8 ug/L, well below the PSV while the second and most recent sample showed a concentration of 30 ug/L. TRhe well has not been resampled. These two results reflect isolated detections not indicative of a plume. The results from the quarterly performance monitoring (2016 on) do not show arsenic and mercury as detected, or COCs.
- Comment 125:** **Table 5-4:** Table 5-4 provides information regarding the COCs included in each of the 16 plumes this investigation presents as well as the SWMUs which are likely sourcing to each plume. Multiple errors exist in this table with regards to plume sources and COCs in each plume. Please review the data presented in this report, as well as the documents related to each SWMU nearby to each plume to ensure each COC and source area are correctly characterized in this table and throughout the report.
- Response 125:** Comment noted. The table will be reviewed for accuracy, updated to reflect new data obtained since the Rev 0 RFI and revised accordingly.
- Comment 126:** **Table 6-1:** The “Sources” noted on the bottom of Page 2 of 2 of the table do not show the “Source” code as shown in the column. Please revise this table by defining the “Source” “A” through “E” with the “Sources” noted at the bottom of Page 2 of 2.

- Response 126:** Agree. It appears both the source coded (A-G) as well as sources source G have been truncated from the printed table. The table has been revised to correct this.
- Comment 127:** **Table 6-3a:** This table appears to be conflicting with its units. For example, spring location RSP-0373 and RSP-0373x indicate “mg/kg” in the “Sample Type and Location” column for sediment at the spring and sediment downstream of the spring; however, in the VOC columns it indicates “µg/L”. Please revise this table by clarifying this discrepancy if appropriate. Please add “mg/kg” to the notes on the bottom of Page 4 of 4. Please see also Table 6-3b and revise accordingly.
- Response 127:** Since the units are [correctly] listed in Column B (Sample Type and Location), the units shown under each COC, in ug/L, will be deleted to remove the confusion. Table 3b has been similarly corrected.
- Comment 128:** **Table 6-3b Analytical Results of Pesticides for Collocated Samples:** This table does not include results from springs east of RSA-117 (e.g. RSP-1504 and RSP-1506) in the broad discharge zone. Exceedances of pesticides and arsenic in collocated samples at these locations were noted in the report. Please address.
- Response 128:** The table has been revised to include the collocated groundwater (spring), surface water, and sediment data for springs in that area. Arsenic results have also been added to the table.
- Comment 129:** **Figure 2-3:** The figure indicates in the legend the Wheeler National Wildlife Refuge boundaries in green; however, the boundary is not shown on the figure. Please revise the figure by adding the Wheeler National Wildlife Refuge boundaries in green.
- Response 129:** Agree. The WNWR boundary does not contribute to the figure and will be removed from the legend.
- Comment 130:** **Figure 2-4:** The figure does not show the names of the sites. This figure would benefit to have the names of the sites on the figure for easy reference. Please revise the figure by adding the names of the sites to the figure.
- Response 130:** Given the 1277 monitoring wells and associated labels it is simply not possible to add the site labels as well on the hard copy maps. Consideration will be given to include the site labels as a layer in the pdf file that the user can toggle on and off as needed. The figure has been revised to make the boundaries of the sites more readily discernible and color filled in accordance with Figure 1-1 (GW responsibility).
- Comment 131:** **Figure 2-5:** Please revise the figure by defining the acronyms “NWT” and “DPT”. Please revise any figures from this point forward by defining all acronyms of the figures. This figure only names one site boundary (i.e.,

MSFC-034). Please revise the figure by also adding all site names to this figure for easy reference to the direct-push technology (DPT) locations.

**Response 131:** Disagree. These acronyms are included in Attachment 1 and spelling each out in legends only further constrains the available space to portray the information. The focus of this graphic to show the distribution of DPT data points. The sites are included to provide reference but it is not possible to label all of the sites given the number of points. The label for MSFC-034 will be removed. Consideration will be given to include the site labels as a layer in the pdf file that the user can toggle on and off as needed.

**Comment 132:** **Figure 2-6 and Figure 2-7:** These figures only name one site boundary (i.e., MSFC-034). Please revise the figures by also adding all site names to this figure for easy reference.

**Response 132:** See responses to Specific Comment 131.

**Comment 133:** **Figure 3-5:** This figure indicates in the notes to “See Figure 3-4 for map view of line CR3-BC”. It appears that Figure 3-6 shows the reflection seismic line “CR3-BC”. If the reference to Figure 3-4 was correct, please revise Figure 3-4 to indicate in the legend where CR3-BC is located and/or show the location on the figure itself with an explanation. Please also revise the figure by indicating the units on the vertical and horizontal lines.

**Response 133:** The Note has been revised to cite the correct figure (3-6).

**Comment 134:** **Figure 3-11:** Please revise the figure by changing “Major Strings” to “Major Springs”. Please also revise the figure by defining the colors (i.e., green, red, yellow, and purple) shown on the block diagram. Please define the symbols noted on the figure (e.g., D/U, U/D, T/MDc, and symbols of the well itself such as screen symbols, water level symbols, etc.).

**Response 134:** “Strings” has been revised to “Springs”. The only color of relevance is the yellow, which denotes the overburden, contrasting the gray which is bedrock. The blue is only to highlight the bedrock surface but will be removed. A legend item will be added for bedrock and overburden colors. It should be apparent to any reader that the green is the ground surface – no legend item will be added. Rather than burdening the figure with a plethora of legend items, all symbols and labels that would otherwise require some legend citation per this reviewer have been removed.